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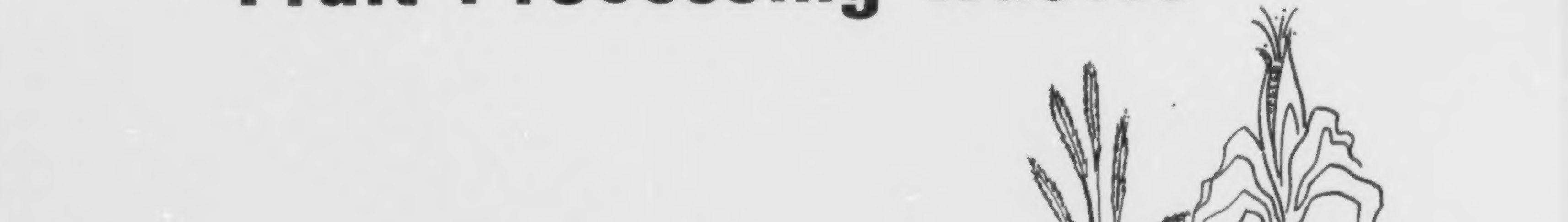

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Aerobic Treatment of Fruit Processing Wastes

A STUDY OF AERATED LAGOON, ACTIVATED SLUDGE
AND ACTIVATED SLUDGE WITH SLUDGE
REAERATION IN THE TREATMENT
OF
FRUIT CANNERY WASTE

**FEDERAL WATER POLLUTION
CONTROL ADMINISTRATION**

DEPARTMENT of the INTERIOR

BY

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SNOKIST GROWERS

12060 FAD
OCTOBER, 1969

FWPCA REVIEW NOTICE

This report has been reviewed by the Federal Water Pollution Control Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Pollution Control Administration.

ABSTRACT

In 1966, it was determined that the Snokist Growers cannery in Yakima, Washington, was in need of further treatment facilities for the cannery waste before the waste could be discharged into the Yakima River. A system of aeration was proposed and a grant sought to aid in construction of facilities and to study the results of the treatment facility following construction. Facility construction proceeded in two stages with addition of an aerated lagoon in 1967 and the addition of additional aeration and clarification facilities in 1968 to complete the treatment system. The treatment system performed more efficiently than initially expected in the original design assumptions, and nearly 99% removal of BOD and COD from the waste stream was accomplished during a major portion of the 1968 processing season.

The treatment systems were studied over the two operating seasons, and operated as an aerated lagoon, as an activated sludge treatment system and as activated sludge system but including sludge reaeration. Data was collected on biological substrate assimilation, sludge growth, oxygen uptake and sludge settleability. Constants were obtained from this data. Success of the treatment system is reported and the costs of treatment computed. It is recommended that aerated lagoon treatment be used where 70 percent removal of BOD is desired and suspended solids are permissible in the effluent. Activated sludge treatment is recommended for greater than 90 percent BOD removal and where effluent suspended solids must be minimized.

This report was submitted in fulfillment of Grant No. 12060 FAD between the Federal Water Pollution Control Administration and Snokist Growers of Yakima, Washington.

CONTENTS

Page

Abstract iii

Conclusions 1

Introduction 3
  Purpose 3
  Scope 3
  Background 4
  Treatment Theory 6
    Cell Growth 7
    Oxygen Requirements 8
    Aeration 8
    Nutrient Requirements 9
    Sludge Settling & Suspended Solids Removal 9

Design of Facilities 9
  Existing Facilities 9
  Design of 1967 Improvements 10
  Design of 1968 Improvements 11

Construction of Facilities 13
  1968 Construction 14

Operation of Project 16
  Testing 17
    Flow 17
    Sample Testing 17
  1967-1968 Operation 17
    Aerated Lagoon Performance 21
    1967-1968 Activated Sludge 21
    Buffering Capacity & pH Control 28
    Nutrient Feeding 30
    Sludge Settleability 30
    Shutdown and Startup 30
    Conclusions Drawn at the End of the 1967-1968 Processing Season 31
  1968 Processing Season Operation 31
    Flow 32
    Testing Results 32
    pH 40
    Nutrient Feeding 40
    Sludge Settling Characteristics 42
    Startup 43

	Page
Discussion	43
Waste Load	43
Cost of Treatment	47
Substrate Removal	50
Biological Growth	59
Oxygen Requirements	69
BOD & COD Content of Biological Sludge	74
Nutrient Requirements	75
Effects of Nutrient Deficiency	79
Biological Solids Removal	82
Sludge Wasting & Disposal	85
Aeration Basin Temperature Prediction	85
Recommendations	89
Future Studies	89
Future Operation	89
Future Designs	90
Acknowledgement	91
Bibliography	93
Appendix A	95
Appendix B	105
Appendix C	111
Appendix D	126

FIGURES

Figure Page

1. Schematic Flow Diagram - 1967-1968 Processing Season 18
2. Treatment Facilities - 1967-1968 Processing Season 19
3. Flow - 1967-1968 Processing Season 20
4. 1967-1968 Aerated Lagoon Performance - BOD 22
5. 1967-1968 Aerated Lagoon Performance - COD 23
6. 1967-1968 Aerated Lagoon Performance - VSS 24
7. 1967-1968 Activated Sludge Performance - BOD 25
8. 1967-1968 Activated Sludge Performance - COD 26
9. 1967-1968 Activated Sludge Performance - VSS 27
10. 1967-1968 Aerated Lagoon Performance 29
11. 1967-1968 Activated Sludge Performance - pH 29
12. Schematic Flow Diagram - 1968 Processing Season . . . 33
13. Treatment Facilities - 1968 Processing Season 34
14. Flow - 1968 Processing Season 35
15. 1968 Treatment System Performance - BOD 36
16. 1968 Treatment System Performance - COD 37
17. 1968 Treatment System Performance - VSS 38
18. 1968 Treatment System Performance - pH 41
19. Crystal Clear Clarifier Effluent During 1968 Processing Season 44
20. COD Removal Rate vs. Concentration 51
21. COD Removal Rate vs. Concentration 52
22. COD Removal Rate vs. Concentration 53
23. COD Removal Rate vs. Concentration 54
24. COD Removal Rate vs. Concentration 55
25. COD Removal Rate vs. Concentration 56
26. COD Removal Rate vs. Concentration 57
27. COD Removal Coefficient vs. Temperature 58
28. BOD Removal Rate vs. Concentration at 20° C. 60
29. Net Sludge Growth vs. COD Removal Rate 62
30. Net Sludge Growth vs. COD Removal Rate 63
31. Net Sludge Growth vs. COD Removal Rate 64
32. Net Sludge Growth vs. COD Removal Rate 65
33. Net Sludge Growth vs. COD Removal Rate 66
34. Net Sludge Growth vs. COD Removal Rate 67
35. Endogenous Respiration Rate vs. Temperature 68
36. Oxygen Uptake Rate vs. COD Removal Rate 71
37. Oxygen Uptake Rate vs. COD Removal Rate 72
38. Oxygen Uptake Rate vs. COD Removal Rate 73
39. BOD, COD Equivalent of VSS 76
40. Nitrogen and Phosphorus Content of Biological Sludge . 78
41. Nitrogen and Phosphorus Requirements for Treatment . . 80
42. Sludge Volume Index vs. COD Removal Rate - 1968 . . . 84
43. Aeration Basin Temperature Relationship 88
A-1. Large Aeration Basin Showing Three of the Four 60 H.P. Aerators, 150 H.P. Aerator, PVC Lining on Dike, and Influent Structure 100

FIGURES - Continued Page

A-2. Waste Treatment System from Screening Station Platform 101
A-3. 30 H.P. Aerators in Small Aeration Basin 101
A-4. Large Aeration Basin - Aerators Operating 102
A-5. Final Clarifier; Small Lagoon Screening Station, Cannery Building and Sludge Pump Building in Background 102
A-6. Sludge Recirculation Pumps and Piping in Sludge Pump Building 103
A-7. Wastewater Laboratory Interior 104
B-1. Typical Daily Processing Flow 110
C-1. Sludge Settling Curves 112
C-2. Sludge Settling Curves 113
C-3. Sludge Settling Curves 114
C-4. Sludge Settling Curves 115
C-5. Sludge Settling Curves 116
C-6. Sludge Settling Curves 117
C-7. Sludge Settling Curves 118
C-8. Sludge Settling Curves 119
C-9. Sludge Settling Curves 120
C-10. Sludge Settling Curves 121
C-11. Sludge Settling Curves 122
C-12. Sludge Settling Curves 123
C-13. Sludge Settling Curves 124
C-14. Sludge Settling Curves 125
D-1. YSI Standardization Curve 128
D-2. YSI Correction Curves 129
D-3. Oxygen Uptake Rate 130
D-4. Oxygen Uptake Rate 131
D-5. Oxygen Uptake Rate 132
D-6. Oxygen Uptake Rate 133
D-7. Oxygen Uptake Rate 134
D-8. Oxygen Uptake Rate 135

TABLES

Table		Page
I	Facilities Existing at Start of Project	10
II	1967-1968 Aerated Lagoon Performance	21
III	1967-1968 Activated Sludge Performance	28
IV	1968 Processing Season Treatment Results	39
V	Cost of Waste Treatment - Total System	47
VI	Estimated Costs of Separate Methods of Treatment .	48
VII	Aerator Oxygen Transfer Efficiency	74
A-I	Costs of Construction of Treatment Facilities . . .	96
A-II	Manufacturers or Suppliers of Major Equipment . . .	98
A-III	Cost of Operation of Treatment Facility	99

CONCLUSIONS

Conclusions from this two year study of the treatment of fruit processing waste by aeration are as follows:

(1) Activated sludge or contact stabilization treatment of fruit processing waste at low rates (below 0.4 mg COD removed per day per mg MLVSS) will provide greater than 90 percent removal of organic load and removal of solids from the effluent. The activated sludge process does as adequate a job as contact stabilization and would be recommended because of requiring less facilities and thereby lower cost.

(2) Aerated lagoon treatment can provide greater than 70 percent BOD removal but suspended solids remain in the effluent and are the principle source of effluent BOD and COD. This treatment is considerably less expensive and is recommended if the effluent quality can be tolerated.

(3) "Completely mixed" aeration basins provide effective buffering to avoid pH fluctuation.

(4) Final clarification for activated sludge or contact stabilization is successful at low surface loading rates (below 400 gallons per square foot per day), made necessary by the slow-settling sludge developed, and with vacuum type sludge removal.

(5) Nutrient addition is necessary to achieve successful treatment. Nutrient savings can be made by increasing the amount of biological sludge in the system, thus decreasing the waste loading rate on the sludge. This allows a greater destruction of sludge by endogenous respiration which returns nutrient to the system and cuts down the amount necessary to add. Activated sludge or contact stabilization treatment is necessary to accomplish this.

(6) Surface aerators accomplished adequate mixing at 0.3 HP/1000 cubic feet and provided 2 pounds of oxygen transfer per horsepower hour under operating conditions.

(7) PVC sheeting is a suitable basin lining material provided adequate diligence is expended in assuring sound field welds at all joints. It is recommended that the bottom be covered with sufficient material to prevent it from floating even if gas should accumulate beneath it.

(8) The biological sludge developed seemed to be independant of the type of fruit processing waste and had the following characteristics:

(a) about 90 percent volatile
(b) settled very slowly
(c) settling improved at low COD and BOD removal rates
(d) mg COD/mg VSS = 1.39
(e) mg BOD/mg VSS = 0.3 + 0.28 x BOD removal rate
(f) mg Organic N: mg Organic P: mg VSS = 0.087: 0.016: 1

(9) Net Sludge Growth/day = C x Substrate removed/day - k_t x MLVSS

where $c=0.49 \frac{\text{mg VSS formed}}{\text{mg COD removed}}$ for Pear processing waste

$c=0.46 \frac{\text{mg VSS formed}}{\text{mg COD removed}}$ for Peach processing waste

$c=0.57 \frac{\text{mg VSS formed}}{\text{mg COD removed}}$ for Apple processing waste

$k_t=0.115 \times 1.14^{(T-20)} \frac{\text{mg VSS destroyed}}{\text{mg MLVSS-day}}$

=Endogenous respiration rate at T °C

(10) Substrate removal rate = f_t x Substrate Concentration

$f_t=0.017 \times 1.16^{(T-20)} \frac{\text{mg COD removed}}{\text{mg MLVSS-day-mg/l COD}}$

$=0.068 \times 1.16^{(T-20)} \frac{\text{mg BOD removed}}{\text{mg MLVSS-day-mg/l BOD}}$

= Substrate removal rate coefficient

(11) Oxygen required/day = a x substrate removed/day + b x k_t x MLVSS

a=0.34 mg O_2 required/mg COD removed

=0.46 mg O_2 required/mg BOD removed

b=1.2 mg O_2 required/mg VSS destroyed by endogenous respiration

(12) Cost of treatment is estimated to be:

$0.041/#BOD removed for Aerated Lagoon
$0.061/#BOD removed for Activated Sludge
$0.067/#BOD removed for Contact Stabilization

INTRODUCTION

PURPOSE

The purpose of this project, "Pollution Prevention by Aeration of Fruit Processing Waste," carried out by Snokist Growers, Yakima, Washington, was to develop a treatment system whereby 90% of the organic content of the waste from their fruit cannery would be removed prior to the wastes discharge into the Yakima River, a tributary of the Columbia River. This organic matter to be measured as biochemical oxygen demand (BOD) was to be removed according to requirements of the State of Washington Water Pollution Control Commission which also called for removal of suspended solids from the effluent to the river. Also, operating data and experience was to be gained on the methods of treatment proposed in order to evaluate them and develop criteria for the design of other systems on similar waste streams in other locations. The collection of data on construction methods and costs of operation would be included in the project in order to help judge the feasibility of the treatment.

Three methods of treatment by aeration were selected for study and comparison: (1) Aerated Lagoon - The aeration of the waste in a completely mixed basin without removal of sludge (suspended solids) from the effluent and without sludge recycle. (2) Activated Sludge - Aeration with suspended solids removal by settling and the return of sludge to the aeration basin, sludge recycle, with the incoming waste. (3) Contact Stabilization or Activated Sludge with sludge reaeration - The sludge is removed from the aeration basin effluent and aerated alone for a period of time prior to return to the aeration basin with the incoming waste.

SCOPE

The scope of this project was to include construction of adequate facilities for the treatment of a waste stream at Snokist Growers cannery, and the study of the treatment methods. The facilities to be constructed would allow concurrent testing of flow through aeration basin or aerated lagoon facility and activated sludge or aeration with sludge return facility during the first season of operation, and further study of the sludge return and aeration process and additionally, sludge return with sludge reaeration during the second season of operation. During the second season of operation, "secondary treatment" or removal of the required amount of organic loading as required by the State of Washington was to have been attained on the full waste stream, in addition to the removal of suspended solids from the effluent, as is also required by the State Water Pollution Control Commission.

Testing was to be carried out to obtain the efficiency of the waste treatment methods and the parameters of aerobic treatment of the waste including the biological growth characteristics, waste assimilation characteristics, oxygen uptake requirements and other characteristics of the waste flow which affect the treatment system operation and design.

These other characteristics include the waste load developed by the process in the cannery and the solids removal problems from the aerated waste stream. It was to be determined if efficiencies could be made in the addition of nutrient chemicals, nitrogen and phosphorus, and the application of power for aeration of the treatment facility by changing operational parameters.

Data on dissolved oxygen, temperature, pH, and settleable solids collected within the aeration basins, data on suspended solids, volatile suspended solids, total and volatile total solids in the influent and the effluent and chemical and biochemical oxygen demand would be gathered over the periods of operation of the facility during the study period. Nitrogen and phosphorus analyses would be made. Analysis of the test data would be made and presented in a final report along with cost records to allow evaluation of the system by others anticipating handling similar waste problems.

BACKGROUND

In 1966 during the fruit processing season, a treatment system consisting of screening of the waste flow from the Snokist Growers cannery, followed by an aeration basin containing two 30 horsepower aerators was being utilized. A small rectangular clarifier was also being used to recirculate the waste settleable solids back to the headworks of the lagoon. Tests had been run by the Washington State Water Pollution Control Commission and by Washington State University which indicated that the system was achieving very poor treatment on the waste stream from the cannery. The State requested that Snokist Growers develop a plan whereby the waste stream entering the Yakima River would meet the requirements of the State of Washington which included 90% removal of the organic content of the waste and the removal of suspended solids from the waste stream. Since the aeration system that had been installed for the cannery was apparently not satisfactory for the waste and its treatment, there was considerable discussion as to the methods of attaining the State's requirements. An analysis of the data accumulated by Snokist Growers personnel, the State Water Pollution Control Commission and the Washington State University indicated that the system was grossly overloaded and did not give a true indication of what a properly designed system could yield in the way of treatment.

It was then decided to seek a Research and Development grant from the federal government who had shortly before that time announced a program whereby treatment projects of a research and development nature could be partially financed in order to develop data on systems for the treatment of industrial wastes. A system whereby stage construction would be made toward eventual complete treatment of the waste was decided upon and where the following year's operation would consist of an aerated basin without sludge settling or sludge return would be used to treat a majority of the waste flow and where the existing system would be used as an activated sludge system on a small portion of the waste flow in order to gather testing data on each type of system. Following one year of operation in this manner, further facilities were to be constructed in order to allow sludge return and suspended solids removal from the waste coming from the aeration basin and, in addition, would allow recirculation of the sludge removed through the small existing aeration basin for sludge reaeration prior to its remixing with the influent waste flow in the large aeration basin.

This construction and operating schedule was approved by the Water Pollution Control Commission since it did not appear feasible to install complete treatment facilities for the first season because of equipment delivery time and, because of the many unknowns surrounding the process, the design would be quite difficult and would necessarily be based on many assumptions which had not been confirmed in any operating facility to that date.

Aeration of wastes for their treatment is not a new concept but has been tried quite extensively on pulp and paper waste streams and somewhat in the fruit and vegetable processing industry. Results of aeration of wastes similar to the waste stream that was experienced at Snokist Growers was unknown so that parameters for the design of a system of this type had to be largely derived from knowledge of the basic treatment process from operations on other types of waste and from the meager data which was available from the studies by the State University and Pollution Control Commission. In 1960, the treatment of industrial waste in so-called aerated lagoons (1) was being developed along with surface aerators which alleviated the necessity of extensive piping and blower arrangements. These surface aerators which consist of a gear motor driving an open impeller were developed by several manufacturers and although they are of different shapes, each manufacturer's claims are for approximately the same efficiency of oxygen transfer. These aerators allow the aeration of open basins without fixed linings and without as rigid compliance to basin configuration as was necessary for diffused air aeration. Also, surface aerators tended to give the basin's contents a more "complete mixed" nature when sufficient horsepower was available to the basin. This completely mixed state within the basin allowed the use of "complete mix" theory for the biological treatment process and, in addition, allowed the entire contents of the aeration basin to assimilate the waste flow as it enters the basin, thereby giving an increased buffer capacity for high strength, variable strength, and high or low pH waste streams.

The development of these surface aerators by equipment manufacturers and their acceptance into use (as attested by the existing installation of two 30 horsepower aerators in an aeration basin at the cannery) was not accompanied by development of theory and parameters for use in the actual treatment process.

TREATMENT THEORY

The theories of biological treatment have been published by several authors, including Eckenfelder, Stewart and Pearson [1, 2, 3, and 4]. These theories, generally based on theory derived from observation of culture growth and reactions by bacteriologists and expanded for use with biological waste treatment systems are generally not too far apart and a composite theory of waste treatment process which can be incorporated into design can readily be attained therefrom. The attainment of a completely mixed system by the use of the aeration methods previously described allow the use of steady state removal of substrate (BOD and COD) by the biological mass measured as volatile suspended solids (VSS) according to these kinetic equations. The Michaelis-Menton Kinetic equation has been suggested as most closely describing substrate (COD and BOD) removal. This equation establishes the BOD and COD removal as equal to the maximum rate of removal of BOD or COD per unit mass of organisms times the residual BOD or COD concentration in a solution, divided by the sum of this residual BOD or COD and the residual BOD or COD at one-half the maximum substrate removal rate. Equation (1) shows this relationship where

$$R = \frac{Fs}{S+s} \qquad \text{Michaelis-Menton Rate Equation} \qquad (1)$$

R = BOD or COD removal rate mg BOD, COD/mg MLVSS-day
F = Maximum removal rate
S = BOD or COD concentration at $R = 1/2\ F$, Michaelis Constant
s = BOD or COD concentration, substrate concentration

This equation, when R is plotted against s, the concentration, provides a curve which starts upward from zero and gradually decreases in slope until it is horizontal at the asymptotic line which represents F. Since F is usually large as compared to a normally operating treatment system where R is normally much less than one, this equation can be substituted by a straight line equation such as equation (2)

$$R = fs \qquad \text{Simplified Rate Equation} \qquad (2)$$

$$f = \text{BOD or COD removal coefficient} \quad \frac{\text{mg BOD or COD removed}}{\text{mg MLVSS-day-mg/l BOD or COD}}$$

without introducing a sizable error. This straight line which has a slope f is valid only for low values of R. This slope f which we will term the BOD or COD removal coefficient can be much more readily obtained from operating data of treatment systems than can be the two constants F and S which must be obtained in order to use equation (1). The substrate BOD or COD concentration in a completely mixed system (s) is a constant since the entire contents are completely mixed and the effluent is also of this same concentration. This provides a constant base concentration so the kinetic equations (1) and (2) become valid only in a completely mixed system.

Cell Growth

It has been observed both from the bacteriological culture experiments and subsequent waste treatment experiments that there is a particular conversion rate of substrate to cell material which is a constant for a particular waste and waste system. This constant represents the milligrams of cellular material formed from the removal by organisms of a milligram of BOD or COD from the waste. This constant which is always less than one reflects that the remaining amount of energy in the removed BOD and COD is utilized in the formation of the cells. The constant ratio of conversion apparently holds true regardless of removal or reaction rate and activity of the biological mass. It has also been shown that there is a rate of destruction of cells which occurs simultaneously with the cell growth. This destruction, termed endogenous respiration, is apparently not affected by the reaction rate of treatment system, but is probably affected by biological activity, primarily linked to the temperature of the system. The net sludge growth, therefore, can be presented as shown in equation (3)

$$\text{Net Sludge Growth} = c\cdot\text{BOD or COD removed/day} - k\cdot\text{MLVSS} \qquad (3)$$

c = Sludge Growth Constant-mgVSS formed/mg BOD or COD removed
k = Endogenous Respiration Rate-mgVSS destroyed/mgMLVSS-day
MLVSS = Mixed liquor volatile suspended solids

The MLVSS is assumed proportional to the active biological mass in the system. Equation (3) can be divided by the mixed liquor volatile suspended solids and since equation (4) is the definition of removal rate, equation (5) can be formed.

$$R = \frac{\text{BOD or COD Removed/Day}}{\text{MLVSS}} \qquad (4)$$

$$G = cR - k \quad \text{Net Sludge Growth Rate Equation} \qquad (5)$$

G = Net Sludge Growth Rate mg VSS/mgMLVSS-day

MLVSS here refers to the total weight of volatile suspended solids in the treatment system and the net sludge growth rate (G) consists of cells or volatile suspended solids accumulated in the system, those which are wasted from the system as carryover in the effluent and those intentionally removed by wastage of settled solids, divided by the total VSS in the system. In a steady state system the effluent substrate would remain constant as would the MLVSS and, therefore, so would the net sludge growth. In a non-steady state system, a portion of the net sludge growth could be accumulated in the system or excessive volatile suspended solids wastage could be carried on and the MLVSS increasing or decreasing, or the substrate could vary. The reciprocal of the Net Sludge Growth Rate is the "Sludge Age" of the biological solids in the system.

Oxygen Requirements

In an aerobic biological treatment system, oxygen is required for energy production for conversion of the substrate to cellular matter and also for the continual maintenance of the biological mass or endogenous respiration. The oxygen required in a steady state operating treatment system can be computed by using equation (6).

$$O_2 = a \cdot \text{BOD or COD removed} + b \cdot k \cdot \text{MLVSS} \qquad (6)$$

O_2 = Oxygen required
a = constant, mgO_2 required/mg BOD or COD removed-day
b = constant, mgO_2 required/mg VSS-day

By dividing equation (6) by the MLVSS we obtain equation (7), which can be used to evaluate the constants in the equation from operating data.

$$O_2/\text{MLVSS} = a \cdot R + b \cdot k \qquad (7)$$

Aeration

Surface aerator manufacturers have done considerable work on their own impeller designs in order to achieve their optimum oxygen transfer efficiency and in order to evaluate their particular machine's performance. Most surface aerator manufacturers claim to get between 3.5 and 4 pounds of oxygen transferred per hour per horsepower hour expended at "Standard conditions". These standard conditions include clear, suspended solids and organic-free water, one atmosphere of pressure (sea level), temperature at 20°C. and 0mg/l of dissolved oxygen. Solids and organics in the water lowers the ability for the water to take gaseous oxygen into solution as rapidly as clear water does and, therefore, these figures must be reduced when being applied to a waste treatment system. Also, the aerators are evaluated at zero dissolved oxygen so a maximum dissolved oxygen differential exists between the surrounding gaseous oxygen in the air being fused into the water by the impeller's action and the water itself. In a treatment system a certain amount of dissolved oxygen must be maintained in order to sustain the biological growth and not cause oxygen deficient conditions in a portion of a system. This 1 to 2 milligrams per liter dissolved oxygen which must be maintained decreases the dissolved oxygen deficit, the driving force for solution of oxygen into the water, which also reduces the factor presented by the companies for their aerators. These two corrections, usually referred to as alpha and beta, must be used for design. Taking these factors into account, an oxygen solution capacity of approximately two pounds of oxygen per horsepower hour expended is normally expected from surface aerators of this type during actual operation in the field.

Nutrient Requirements

It has been recommended [2] that a BOD to nitrogen to phosphorus ratio in the influent to a biological system be maintained at 100:5:1 in order to assure proper biological growth conditions. This amount of nitrogen and phosphorus is required to provide the cells with adequate nutrients to form the cellular protein. It has been suggested elsewhere [9] that variation in nutrient feeding should follow the sludge age or BOD removal rate.

Sludge Settling and Suspended Solids Removal

At the beginning of this project there was very little published data on sludge characteristics from industrial wastes and none on fruit processing wastes which was applicable to the conditions which were anticipated. It had been observed, however, that sludge growths, when obtained from carbohydrate wastes resist settling out and resist flocculation into a thicker mass. This was a portion of the reason for delaying the installation of full scale clarification facilities until the second year of the project in order to allow further study of the settling and clarification characteristics during the first season of operation.

DESIGN OF FACILITIES

In the design of facilities for this project, three criteria were involved.

1. To utilize the facilities already existing to the maximum amount possible.
2. To achieve a system whereby continued high degree of treatment would be available for the waste system in the future at the design loadings.
3. To make the system flexible enough to gather data over a wide range of operation for evaluation of the treatment system and the three proposed types of treatment.

EXISTING FACILITIES

Facilities which had been constructed prior to 1967 were available at the start of the project. The design for the project attempted to incorporate these facilities as fully into the treatment system as was possible. A screening station which consisted of two vibrating screens with a lift station to lift waste over the screens and to an elevation higher than the treatment facilities was available. This screening station is adequate for the waste load and does a suitable job of removing large solids particles from the waste stream leaving a screened effluent with nearly the entire organic load in the soluble state. There also existed an earth basin with sprayed-on asphalt lining to prevent waste infiltration into the ground water, equipped with two 30 horsepower turbine type surface aerators. A hopper bottom rectangular clarifier accompanied this aeration basin.

and a return pump to recirculate settled sludge from the bottom of the hopper cones to the headworks of the aeration basin.

An outfall sewer from the aeration basin location to the Yakima River was also available and was hydraulically adequate to carry the waste from the treatment site to its discharge in the Yakima River.

TABLE I

Facilities Existing at Start of Project

1. Lift Pumps & Screening Station - Open Impeller Pumps and two Vibrating Screens
2. Aerated Basin - Earth Dikes - Asphalt Lined
   136' x 236' @ Water Surface x 8' Deep - 1.5 MG Capacity
3. Aerators - 2 - 30 HP Turbine Aerators
4. Clarifier - Rectangular, Hopper Bottom - 200 gpm pump for sludge removal - W.S. = 1070 ft.^{2}, Depth = 12', Vol. = 47,700 gal.
5. Outfall Line to River

DESIGN OF 1967 IMPROVEMENTS

The 1967 improvements were designed to provide an aerated lagoon facility of adequate capacity to treat the waste which was not capable of being handled in the existing aeration basin clarifier system. Design loading based on Snokist Growers' records and the studies made by Washington State University and the Washington Water Pollution Control Commission in 1966 were as follows:

1967 Design Loading
Flow 2 MGD
BOD (after screening) 20,000#/day

Both nitrogen and phosphorus were considered deficient. The existing facility could handle only approximately 10 to 15 percent of this waste load based on the 2#/HP hour-probable transfer capability of oxygen by the existing 30 horsepower aerators.

The design of the aerated lagoon was based upon treatment constants as derived from the data collected by the Pollution Control Commission study and Washington State University in their study. This data was derived by analysis of the two studies and comparison through trial and error analysis of these two sets of data. The following constants were obtained for the new design:

c = 0.6 mgVSS/mg BOD removed
k = 0.05 mgVSS/mg MLVSS-day

$$f = 0.0022 \quad \frac{\text{mg BOD removed}}{\text{MLVSS-day-mg/l BOD}}$$

a = 0.6 mg O_2/mg BOD removed
b = 1.5 mg O_2/mg VSS-day

In a steady state operating condition of an aerated lagoon which enjoys complete mixing, it can be seen that since

G = Net Sludge Growth,
Net Sludge Growth = VSS x Q

and

MLVSS = VSS x V

that

$$G = \frac{Q}{V} = \frac{1}{t} \qquad (8)$$

where

Q = Waste Flow
V = Basin Volume
t = Hydraulic Detention Time-Days

Equation (8) is valid only for completely mixed aerated lagoons. Equation (9) can be derived and is an equation which is also valid for completely mixed aerated lagoons only

$$\frac{1}{t} = cR-k = cfs-k \quad \text{Aerated Lagoon Equation} \qquad (9)$$

An aerated lagoon design was made using 1.7 MGD and 17,000#/day of BOD (85% of the design figures) or a BOD concentration of 1200 mg/l. An effluent BOD of 252 mg/l was computed for a basin of 6 million gallons volume. In addition to this substrate BOD, an assumed factor of .25 x the effluent volatile suspended solids (480 mg/l) as the BOD load of VSS in the effluent was assumed which would give a 372 mg/l total BOD load in the effluent or 69% predicted removal of BOD. The constants assumed would also give a 9,900#/day oxygen demand on the aerators in the lagoon. Based on the limitation of 2# of oxygen transferred per horsepower-hour, 206 horsepower in aerators would be required. Since this 2#/HP-hour figure had not been borne out in actual tests it was decided to install four 60 horsepower aerators or 240 horsepower in aeration capacity on the proposed 6 million gallon basin. This basin was to be 280 feet by 280 feet surface area and 12-1/2 feet in depth with the aerators located in the four corner quadrants. In the actual installation, the aerators were located offset slightly toward the outside corners of the lagoon in order to allow for the possibility of adding additional aeration capacity in the center of the lagoon during the next year's expansion. The horsepower of aerators selected equaled 0.3 HP/1000 cubic feet of basin.

DESIGN OF 1968 IMPROVEMENTS

The 1967 operating season gave us considerably more data with which to design for complete treatment of the entire waste stream. The design loading for the treatment facility for the 1968 expansion to what was intended to be a complete secondary treatment facility as required by the State of Washington Water Pollution Control Commission were as follows:

Flow = 2.5 MGD for 16 hrs/day
BOD = 28,000#/day
COD = 35,000#/day

Treatment parameters for use in the design equations, as presented earlier, were changed somewhat from those assumed for 1967, although data was not sufficient to revise these figures greatly as of that time.

c = 0.6 mg VSS/mg BOD removed
k = 0.05 mgVSS/mg MLVSS-day

$$f = 0.005 \quad \frac{\text{mg BOD removed}}{\text{mgMLVSS-day-mg/l BOD}}$$

a = 0.45 mg O_2/mg BOD removed
b = 1.5 mg O_2/mg VSS-day
Oxygen transfer capability of aerators 2.0#/HP hr.

The 1968 design had to be more complex than the 1967; for complete treatment as was required, it was necessary to remove the suspended solids from the effluent. It was noted during the 1967 season that sludge grown in the aeration basin without sludge recycle, displayed little, if any, propensity towards settling, whereas, the sludge grown in the activated sludge portion even though the clarifier was of poor design and quite inefficient, did show settling characteristics far superior to the sludge from the aerated lagoon. After study of the settling curves from the activated sludge system, it was decided that circular clarifier with a vacuum sludge removal system would be the most efficient for this purpose and that recycling sludge to the aeration basin would be a definite necessity. This would increase the MLVSS to a point where the removal rate of BOD by the organisms was low enough that the sludge would maintain acceptable settling characteristics. An overflow rate of 400 gallons/square foot/day was selected for the design area of the clarifier and the ability to recycle sludge at twice the influent flow rate was deemed desirable.

It was assumed that a volatile suspended solids concentration of 1,800 mg/l could be maintained in the aeration basin during normal operation and using this assumed figure and the constants given above with the design loading, it was determined that a requirement of 396 horsepower would be necessary to supply sufficient oxygen to the aeration basin if the entire waste stream went through the large basin. The addition of a single 150 horsepower aerator, the largest available, in the center of that basin along with the 4 - 60 horsepower aerators installed the previous year, would supply 390 horsepower. This was decided to be sufficient. At steady state conditions, a sludge wasting rate of 12,800#/day of suspended solids was anticipated from the system operating at the loading given.

The clarifier of circular design at an overflow rate of 400 gal/square foot/day and 2.5 MGD design flow was required to contain 6,250 square feet of surface area or would require a 90 foot diameter unit. An 8 foot side water depth would yield a volume of 440,000 gallons for detention time of 4 hours 15 minutes for the design flow. Two sludge recycle pumps, both variable speed, and of 2.5 MGD or 1750 gallon per minute (GPM) capacity would give a sludge recycle ratio of twice the expected waste flow. This recycle ratio could be varied downward as necessary and the two pumps could be utilized to recycle sludge both to and from the small lagoon for reaeration prior to its reintroduction into the large lagoon if settling characteristics of the sludge allowed the sludge recycle rate to be at or less than the single pump capacity.

In order to increase the concentration of the sludge for its haul to land disposal, a flotation sludge thickener was deemed necessary even though no data had been developed to indicate this would be a workable system. Several manufacturers of waste treatment equipment had flotation thickeners available and it was decided that a thickener with a maximum sludge loading of 2#/SF/hour for wasting 900# of waste sludge per hour, a maximum overflow rate of 1.5 gal/min/SF and a minimum dissolved air capacity of 0.3#/minute would be let out for bid and constructed. Included was the ability to add Polymers to aid the sludge flocculation and thickening.

CONSTRUCTION OF FACILITIES

The facilities added onto the existing treatment system at the cannery occurred over two years. In 1967, an additional aeration basin lined with polyvinylchloride (PVC) sheet and equipped with four 60 horsepower column mounted surface aerators was constructed. Also installed was a flow metering and splitter box and necessary piping, boxes and appurtenances to tie the new basin into the influent and effluent system.

The surface aerators were bid upon by four manufacturers of such equipment and included the mounting platform. The aerators are mounted on concrete piers with galvanized rod cross bracing and were accessible from walkways leading from the bank. The earth dikes were constructed by earth moving equipment and compacted with water addition. C-76 class IV concrete sewer pipe with rubber ring joints was installed for influent and effluent piping. The influent flow measuring and diversion box was constructed so that the flow could be proportioned between the two aeration basins and metered through a two foot rectangular weir.

The 0.020 inch polyvinylchloride (PVC) basin liner was selected due to the difficulties which had been experienced with the sprayed on asphalt liner in the original construction of the small existing basin. The manufacturer and supplier of this liner advocated its use without cover and laid directly on the bottom with the exception of around the berm of the dike where an earth cover would be placed to protect the liner from the sun's direct rays, which would tend to age the material. The liner installation went smoothly and apparently a satisfactory installation job was done. However, following about a month of operation of the system, bubbles began to appear in the liner at the water surface. Upon the advice of the manufacturer and concurrence with the engineers of the project, the bubbles were punctured to allow the liner to settle back to the lagoon bottom. Dewatering of the lagoon the following spring, (March, 1968) showed that the liner had failed along several of the "welded" seams which were done in the field. These failures, some of them of considerable length and one of which had parted at least six feet, were apparently allowing wastewater to get underneath the liner and become anaerobic, thereby causing gas to carry the liner to the surface. Repair work was instigated by the cannery in cooperation with the original installer of the liner. This repair work consisted of dividing the liner into sections and its removal from the lagoon to allow shaping of the lagoon bottom beneath the liner to slope upward to the sides of the lagoon which would allow gas to escape, and in addition to remove from beneath the liner the accumulated sludge layer which was nearly an inch thick over much of the bottom prior to replacement of the liner. The liner was replaced and covered with a six inch to one foot layer of round rock to hold it in place and prevent further flotation even if some gas did develop beneath the liner. Another contributing factor to the liner's flotation apparently was the fluctuating ground water table in the area which, during certain portions of the year drops well below the lagoon bottom, whereas, during the spring and summer, when heavy irrigation is carried on in the Yakima Valley, the water table becomes two or three feet above the bottom elevation. This possibly entraps air between the liner and ground water. The PVC liner has given completely satisfactory service since its reinstallation and covering. It would be recommended on future installations that covering of the liner be done at the initial installation as a precautionary measure against unknown problems. It is also recommended that very careful supervision and testing be maintained full time during the liner installation to avoid the possibility of poor field "welding".

1968 CONSTRUCTION

The construction of facilities for 1968 began in February, 1968 with the calling for bids on equipment to be installed during that construction season. Placed out for bids at that time were the 150 horsepower surface aerator, including platform and steel support legs and cross bracing; the suction clarifier mechanism for a 90 foot diameter clarifier; two variable speed sludge pumps with 1750 gallon/minute capacity; and flotation sludge thickener. Following the bid opening on March 1, this equipment was put on order and plans and specifications were begun for their installation. Bids were also called and contracts let on a laboratory building to be built, using a common wall with one of the cannery's warehouses, and to include laboratory space for all of the tests which were to be run for the treatment project and connected research. The laboratory building is of concrete block construction, 22 feet by 36 feet inside dimensions, complete with cabinets, counters and equipment. Considerable additional laboratory equipment was available from the first season's operation and from purchases prior to this project.

Bids were called the latter part of May for construction of auxiliary facilities and for installation of the equipment contracted earlier in 1968. The timing was set up on this contract so as to have the installation of equipment completed for operation during the 1968 season. The actual delivery of the equipment and installation was somewhat delayed so that the clarification operation and sludge return did not get into operation until early September. An early beginning of pear harvest and pear processing allowed more of the season to pass by than had been anticipated. However, the majority of the season was covered by the facility being in operation so that "complete treatment" was experienced, and additionally, a wide range of operating variables were covered to gain added data points for the evaluation of this treatment of fruit processing wastes.

Appendix A contains photographs of equipment and structures utilized in the project. Table I in Appendix A contains costs of construction of facilities including the facilities prior to the beginning of the project. These costs are broken down by items in order to more readily lend the cost data to estimation for other facilities. Appendix A, Table II contains the manufacturer's name of major treatment equipment items utilized for this project.

With the exception of the lagoon liner, no difficulties were experienced with any of the equipment items during the project's operations. However, following the shutdown during the 1968 season of the facilities the aerators on the large aeration basin were operated in February to prevent odors from developing from the sludge in the system. This system had frozen over in December following the shutdown of the processing line and the aerators had been shut down for a period of time prior to restarting when the ice thawed off the basin. Shortly after restarting the aerators, one of the original 60 horsepower aerator gearmotors began sounding quite badly and was shut down. Inspection showed that a misalignment of shafting had occurred and several gear teeth were missing on some of the major gears. The initial tooth breakage was because of a shaft misalignment caused by the shaft slipping out of its bearing. Teeth on other gears in the gearmotor were broken off when pieces of the teeth from the initial broken gear flew into them. There appeared to have been some mismanufacture of the part that slipped out of its bearing since the bearing was supposed to have been a pressed-on tight fit which would not slip off of the shaft. The shaft furnished by the gear manufacturer when replacement parts were ordered appears to be of a better design.

The aeration control system installed in 1968 was intended to alternate the aerators for mixing of the basin and provide the proper amount of aeration required during low loading periods on the treatment system. It incorporated a dissolved oxygen (DO) probe and monitor which programmed a need for additional dissolved oxygen to the aeration system on a programming switchboard. This system functioned satisfactorily and could alternate the aerators on a three hour cycle and call for additional aerators to be on when the dissolved oxygen in the lagoon dropped below a preset level. Although this idea has merit from the standpoint of the saving of aeration power, it may be impractical to alternate the aerators at this frequency and a longer frequency of cycling would be advisable from a mechanical standpoint, since repeated cycling tends to shorten the projected gear life in this type of equipment according to manufacturer's statements.

OPERATION OF PROJECT

The project for the study of aeration of fruit processing wastes was extended over two seasons of operation of the Snokist Growers cannery. The first season of operation, 1967-1968, began in August, 1967 with the processing of pears. Peaches were processed in September and pears were processed again in October until approximately the first of November. Plums and tomato juice were packed concurrently with these products. Apple processing began the first of November and continued with several breaks in processing through May, 1968. During this season activated sludge treatment was carried out with aeration in the small existing lagoon, settling in the existing rectangular hopper bottom clarifier and sludge recirculation from the clarifier into the aeration basin. The new aeration basin was operated as an aerated lagoon, with the effluent going directly to the Yakima River.

The 1968 season saw utilization of the newly constructed clarifier and return sludge system, in conjunction with the large aeration basin to which had been installed additional aeration capacity, as an activated sludge system throughout much of the season. The season began once again with pears in August and continued through peaches in September and back onto pears through November 1st. Once again tomato juice and plums were packed concurrently with these products. For two weeks prior to the end of the pear season, the facility was operated as a "contact-stabilization" unit when sludge reaeration was carried out in the small aeration basin, prior to its return to the large basin and aeration with the screened waste. Following the first of November, the system was once again operated as an activated sludge system with the influent going to the large aeration basin and sludge recycling from the clarifier back to the basin. Apple processing which began near the first of November continued only until approximately December 20 with a one week break for Thanksgiving in the interim. The short apple crop of 1968 prompted this shortened season.

TESTING

Testing procedures for both 1967-1968 and 1968 processing season operations were standardized to the greatest extent possible. Individual data tests were performed as follows.

Flow

Flow was measured as the water passing over a two-foot rectangular weir with end contractions and the water level going over this weir was recorded and the flow computed therefrom. During the 1968 processing season, the water level recorder also had a continuous flow totalizer and read-out so the daily flow from the charts could be checked. When the flow was split between the large and small basins, it was done with the use of a divider plate which split the flow over the rectangular weir. The position of this divider plate was recorded and the flow to the two basins computed from the plate's position and the flow over the weir.

Sample Testing

Laboratory testing of samples collected was done according to Standard Methods [5] for most tests with some exceptions. Appendix B contains the method of testing for all laboratory tests used during the study.

1967-1968 OPERATION

During the 1967-1968 processing season, two methods of treatment of fruit processing waste by aeration were carried out. The first of these methods was the so-called aerated lagoon, or aeration without sludge removal or sludge recycle. The other was aeration with sludge removal from the aerated waste by settling and sludge recycle to the aeration basin or the so-called activated sludge treatment system. Figure 1 shows the schematic flow diagram of the waste treatment systems as they were operated in 1967-1968. As it can be seen from Figure 1, the flow following screening on the vibrating screens was split at the metering box and a portion sent to the aeration basin of the activated sludge system and the remainder to the aerated lagoon. Approximately 18% of the flow was diverted to the small lagoon, the activated sludge system, from approximately August 31 through October 4. After October 4, approximately 15% of the flow was diverted to the small lagoon for activated sludge treatment until November 1 when the activated sludge system ceased to receive flow and the entire flow was diverted to the aerated lagoon. During all of these periods, all of the flow that did not go to the activated sludge system was treated in the aerated lagoon.

Figure 2 is an aerial photograph of the waste treatment system as it operated in 1967. Figure 3 shows the flow to each of the two treatment systems during the 1967-1968 processing season. It also

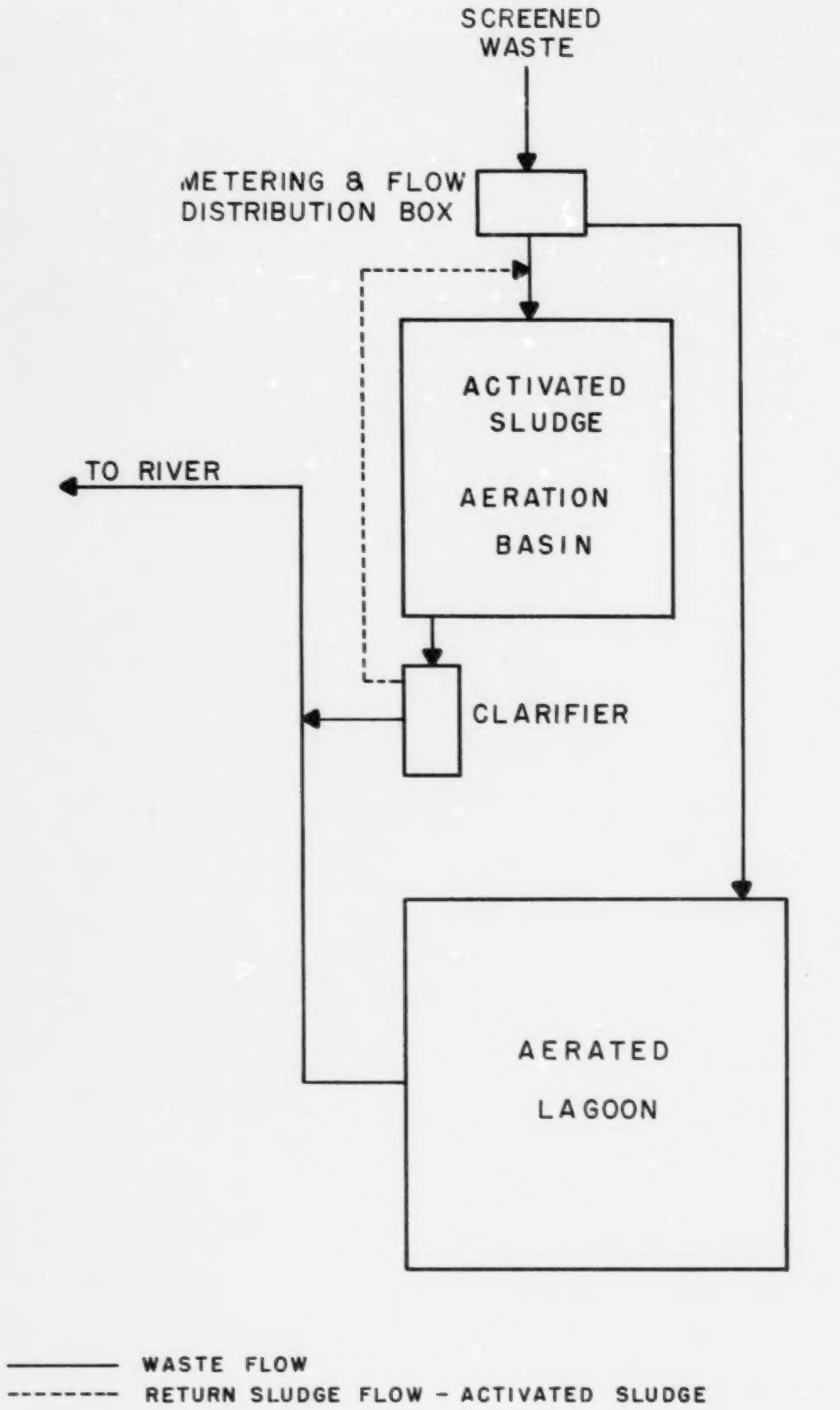
SCREENED WASTE
METERING & FLOW DISTRIBUTION BOX
ACTIVATED SLUDGE AERATION BASIN
TO RIVER
CLARIFIER
AERATED LAGOON
WASTE FLOW
RETURN SLUDGE FLOW - ACTIVATED SLUDGE

FIG. 1. — SCHEMATIC FLOW DIAGRAM 1967-1968 PROCESSING SEASON

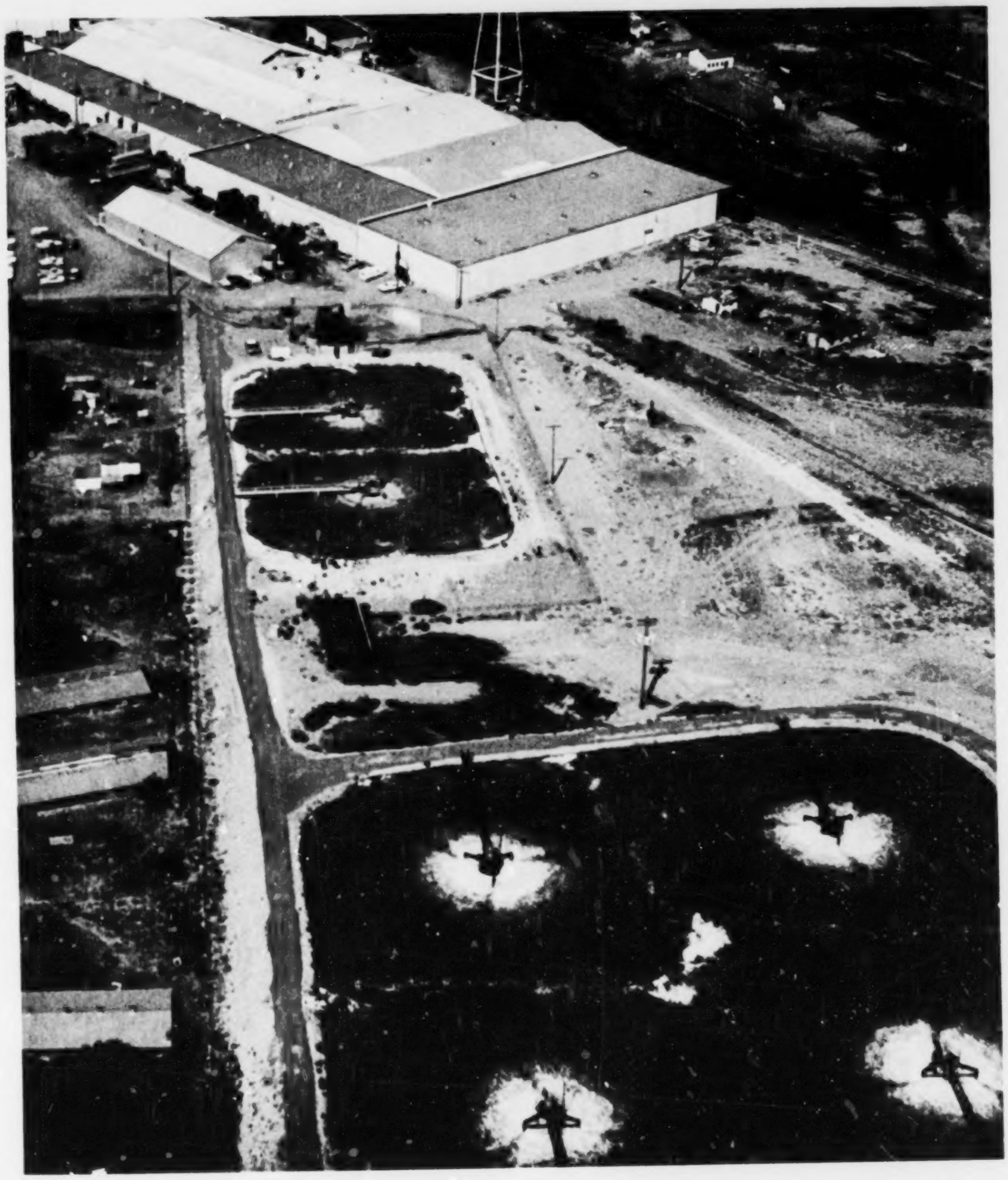

FIG. 2. — TREATMENT FACILITIES 1967-1968 PROCESSING SEASON

AERATED LAGOON, FOREGROUND; ACTIVATED SLUDGE AERATION BASIN, CENTER WITH RECTANGULAR CLARIFIER BETWEEN BASINS; SCREENING STATION, METERING AND DIVISION BOX BEYOND SMALL LAGOON; CANNERY BUILDINGS, TOP.

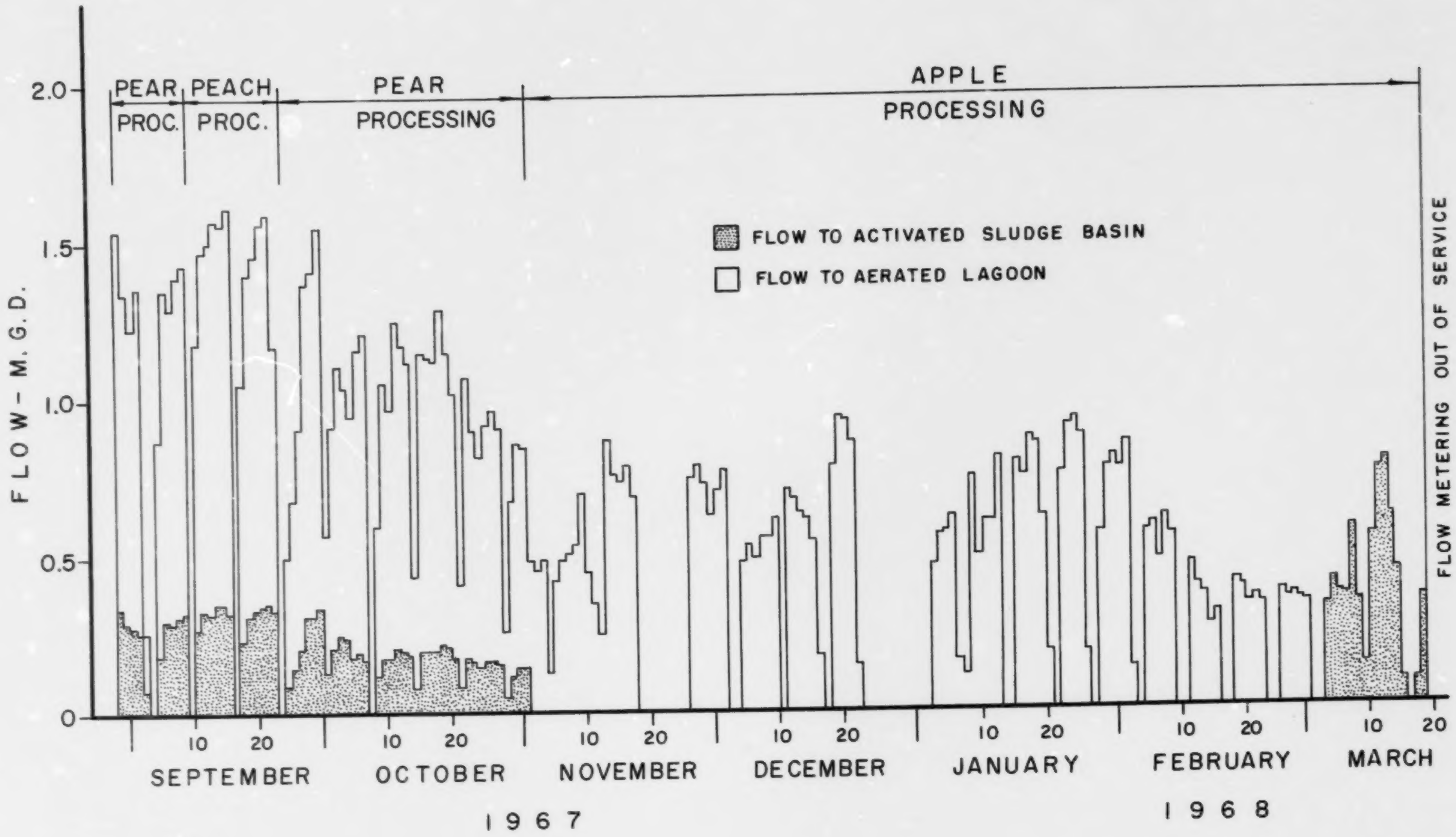

FIG. 3. — FLOW - 1967-1968 PROCESSING SEASON

shows portions of the season during which processing of different products occurred. Tomato juice packing and plum processing also occurred during the peach and pear processing portions of the season but on an inconsistent basis.

Aerated Lagoon Performance

Figures 4, 5, and 6 show the performance of the aerated lagoon system in BOD and COD removal and the quality of the effluent from the aerated lagoon. The data used in plotting these figures and determining these averages was published in an earlier data release [6]. Table II contains the average performance of the aerated lagoon

TABLE II

1967-1968 Aerated Lagoon Performance

	Suspended Solids-mg/l		COD-mg/l		BOD-mg/l	
Period	Influent	Effluent	Influent	Effluent	Influent	Effluent
Pear Processing	375	770	3050	1040	2040	370
Peach Processing	146	830	2150	570	1810	340
Apple Processing (Nov.-Dec.)	62	540	1520	760	1230	190
Apple Processing (Jan.-Feb.)	49	470	1400	620	950	110

	Average Lagoon Detention Time - Days	COD Removal-%	BOD Removal-%
Pear Processing	6	66	82
Peach Processing	4 - 8	73	81
Apple Processing (Nov.-Dec.)	12	50	85
Apple Processing (Jan.-Feb.)	14	56	88

The COD removal efficiency during peach processing is not too reliable due to a small amount of data and possible discrepancies. The effluent volatile suspended solids had higher COD than BOD values resulting in lower COD removal efficiencies.

1967-1968 Activated Sludge

Figures 7, 8, and 9 show the operating performance of the activated sludge system during the 1967-1968 season. The activated sludge system was operated during peach and pear processing and then its operation was terminated until approximately March when the aerated lagoon was taken out of service and the entire waste flow from apple processing put into the small lagoon and an activated sludge system re-established with the use of the rectangular clarifier and sludge return pumping. As can be seen from Figure 7, the BOD removal with activated sludge, or aeration and return of the sludge to the aeration basin, was considerably better than that for the aerated lagoon. It can be seen,

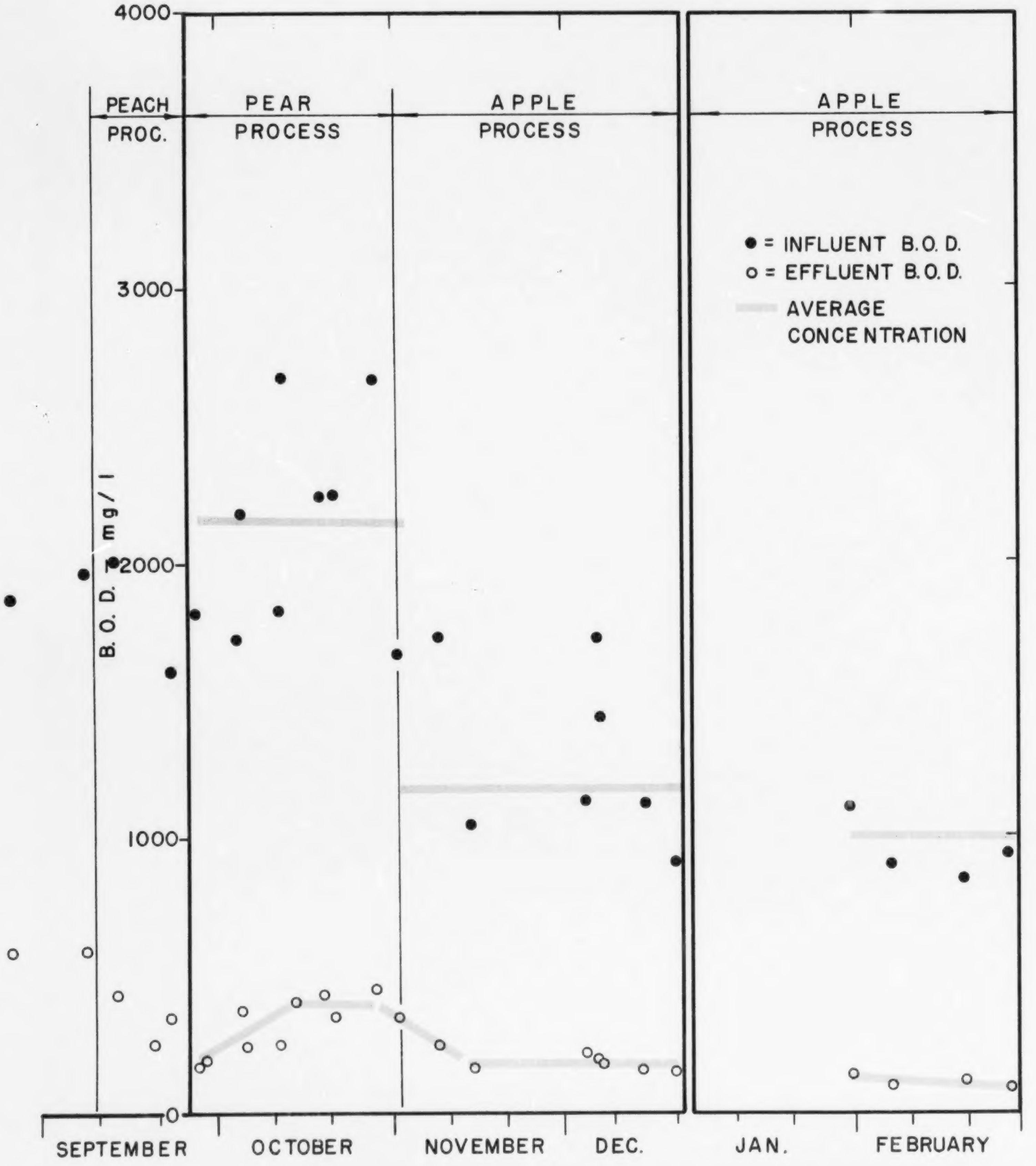

FIG. 4. — 1967-1968 AERATED LAGOON PERFORMANCE - B.O.D.

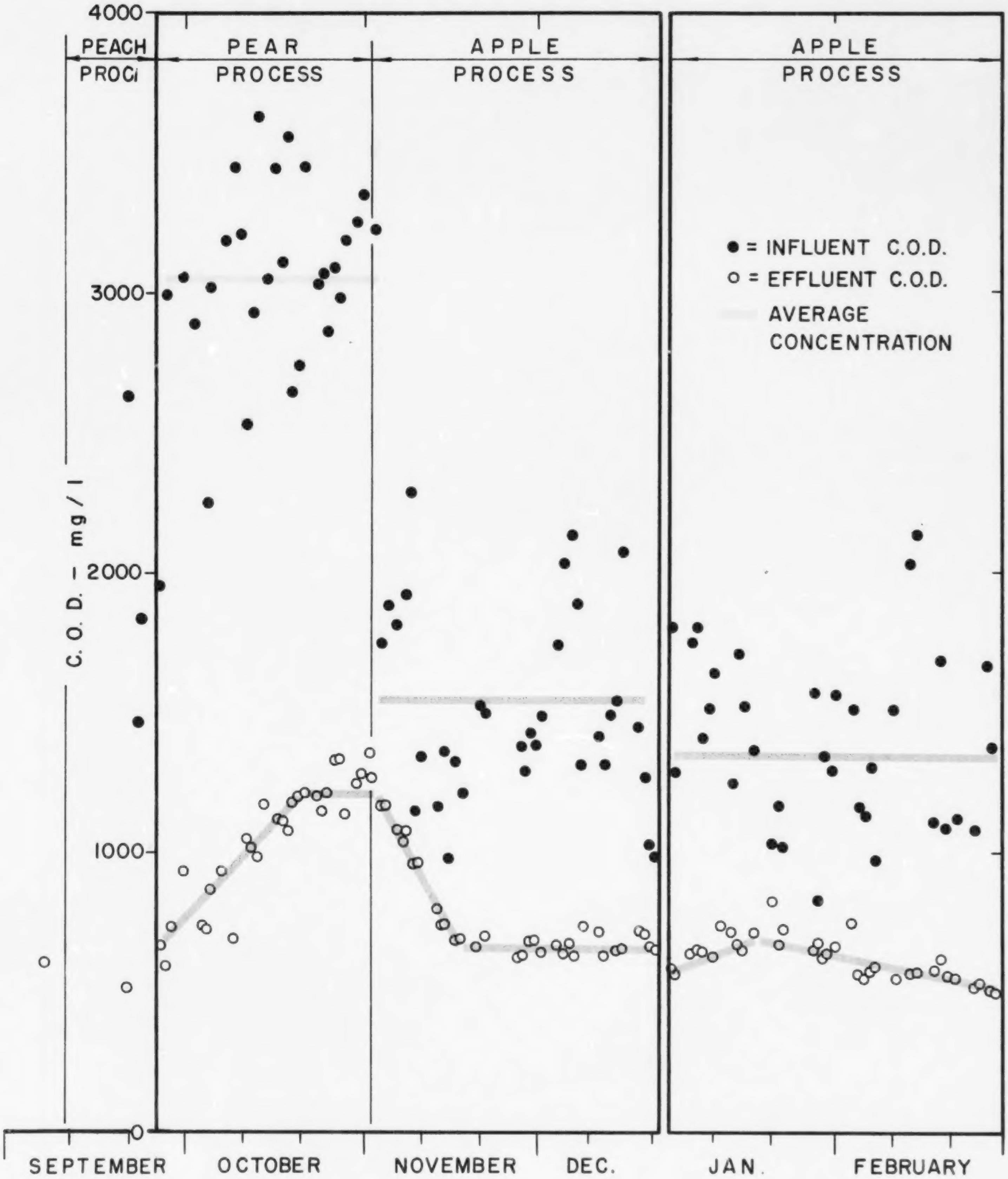

FIG. 5. — 1967-1968 AERATED LAGOON PERFORMANCE - C.O.D.

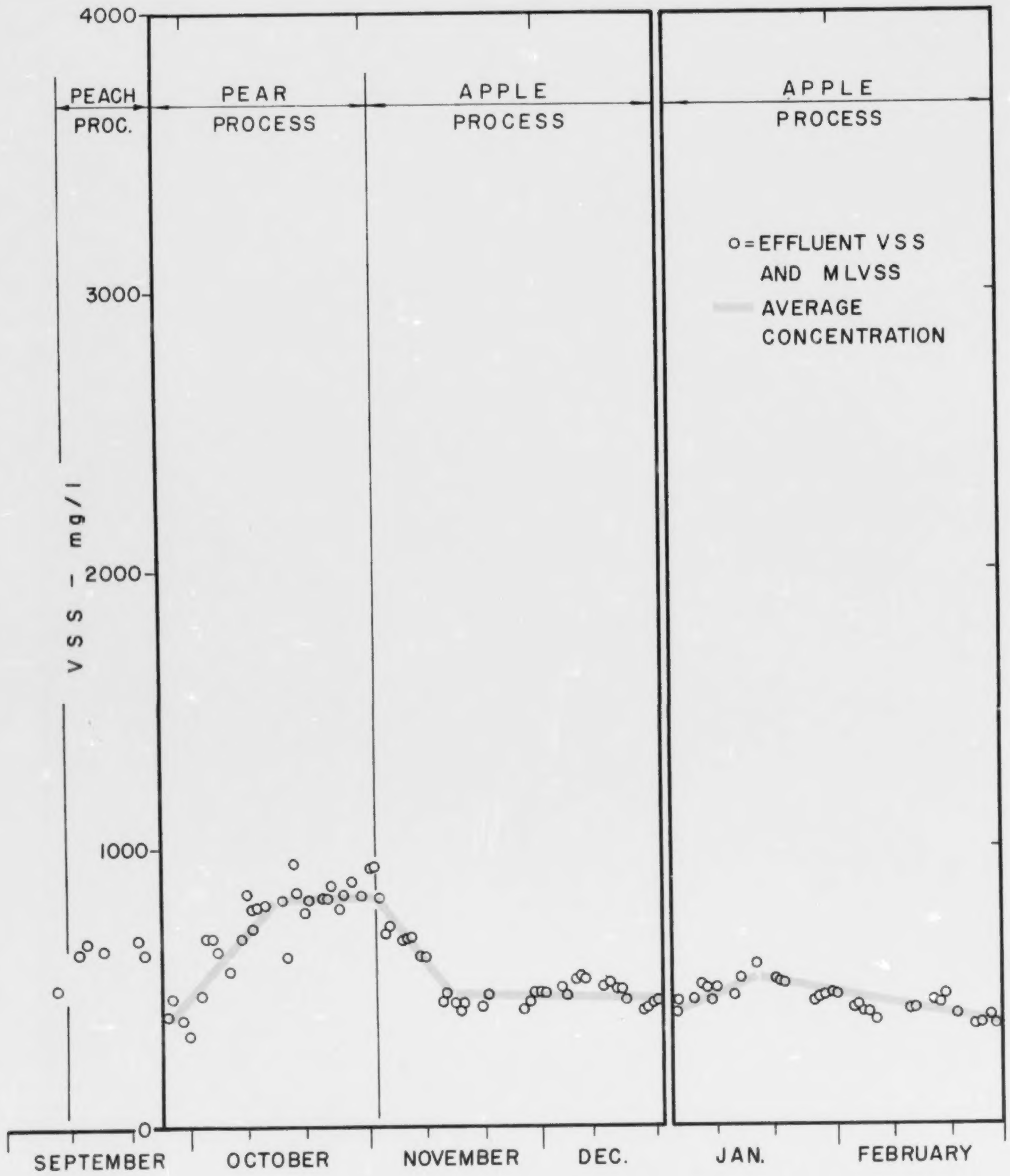

FIG. 6. — 1967-1968 AERATED LAGOON PERFORMANCE- VSS

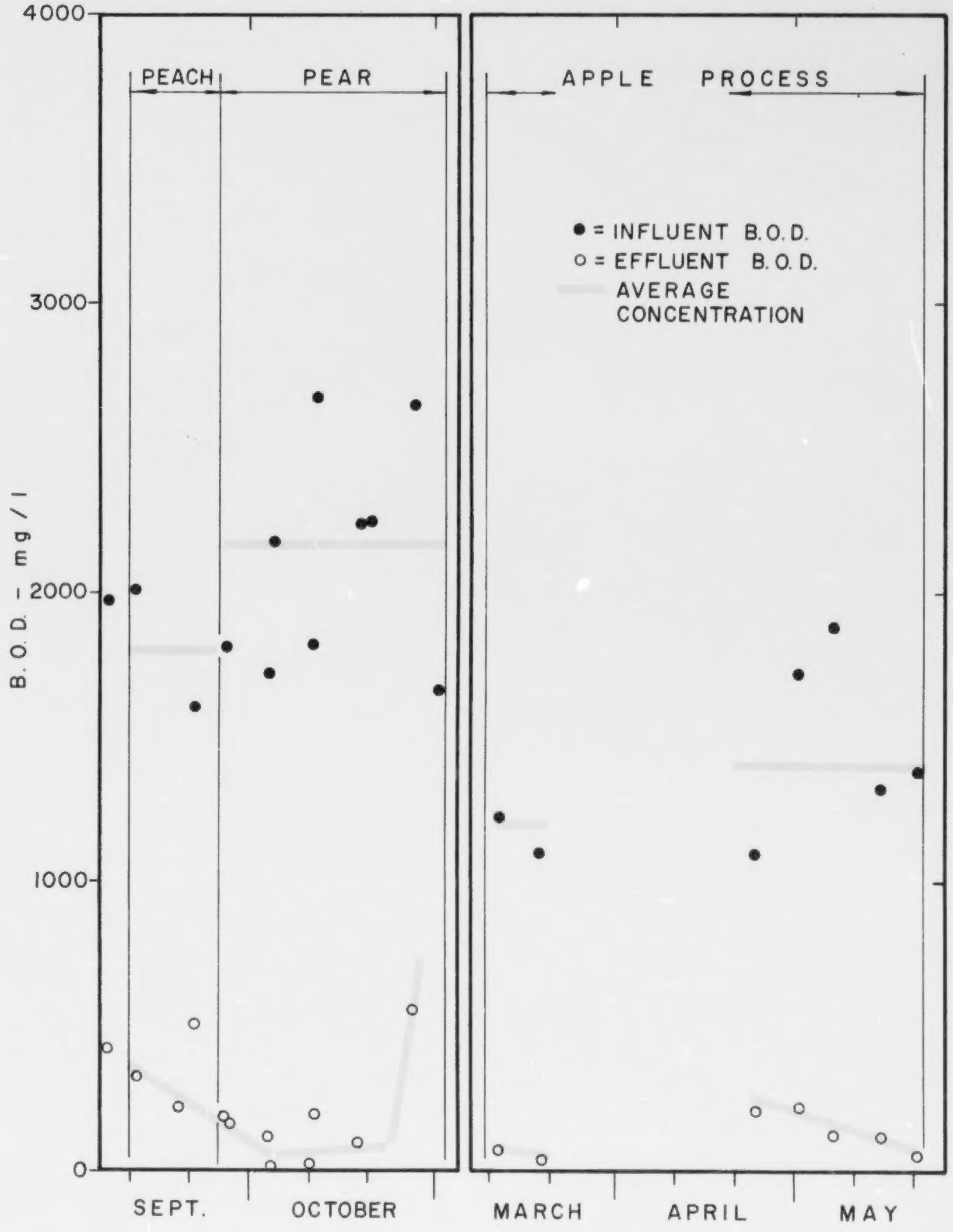

FIG. 7.—1967-1968 ACTIVATED SLUDGE PERFORMANCE-B. O. D.

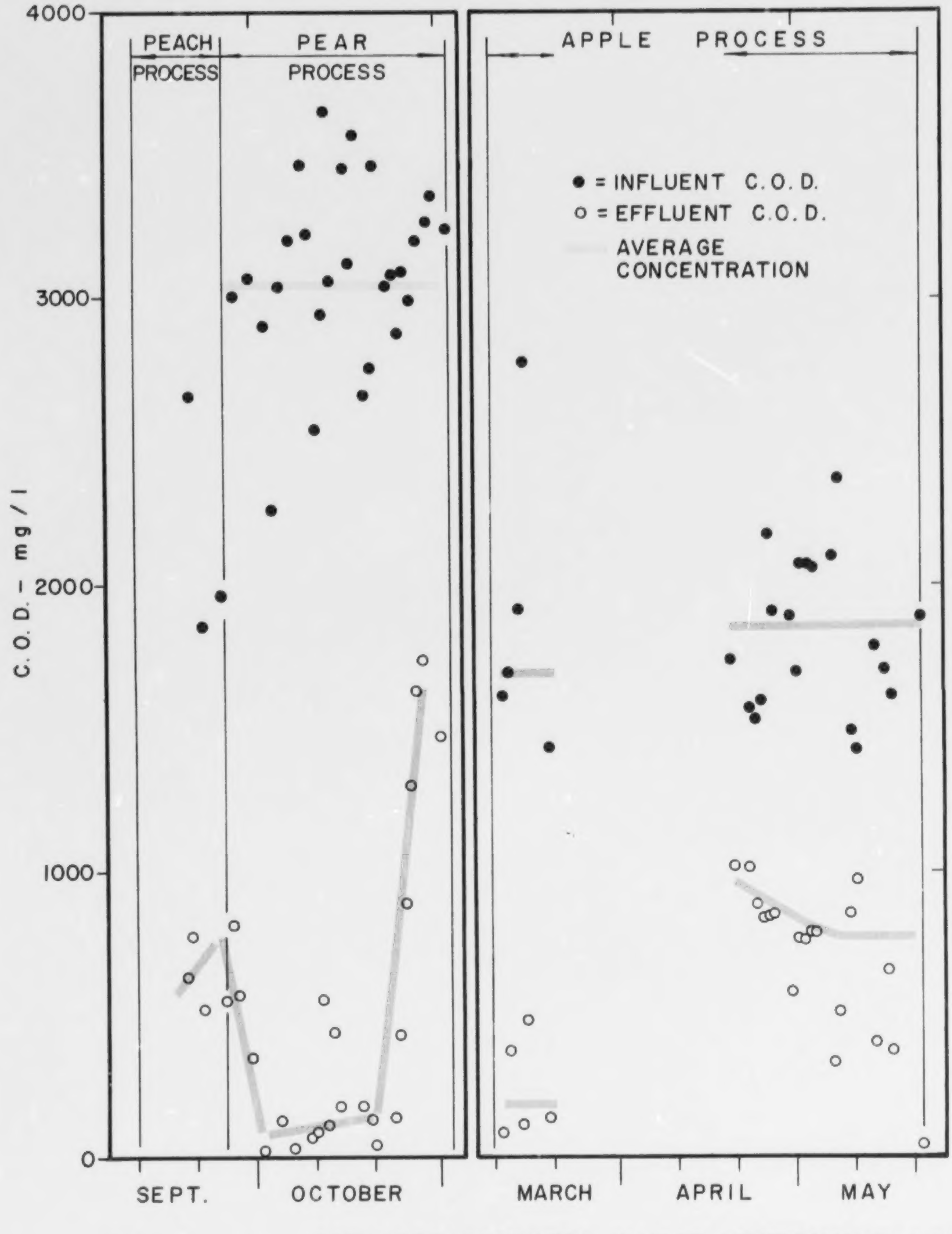

FIG. 8. — 1967-1968 ACTIVATED SLUDGE PERFORMANCE-C.O.D.

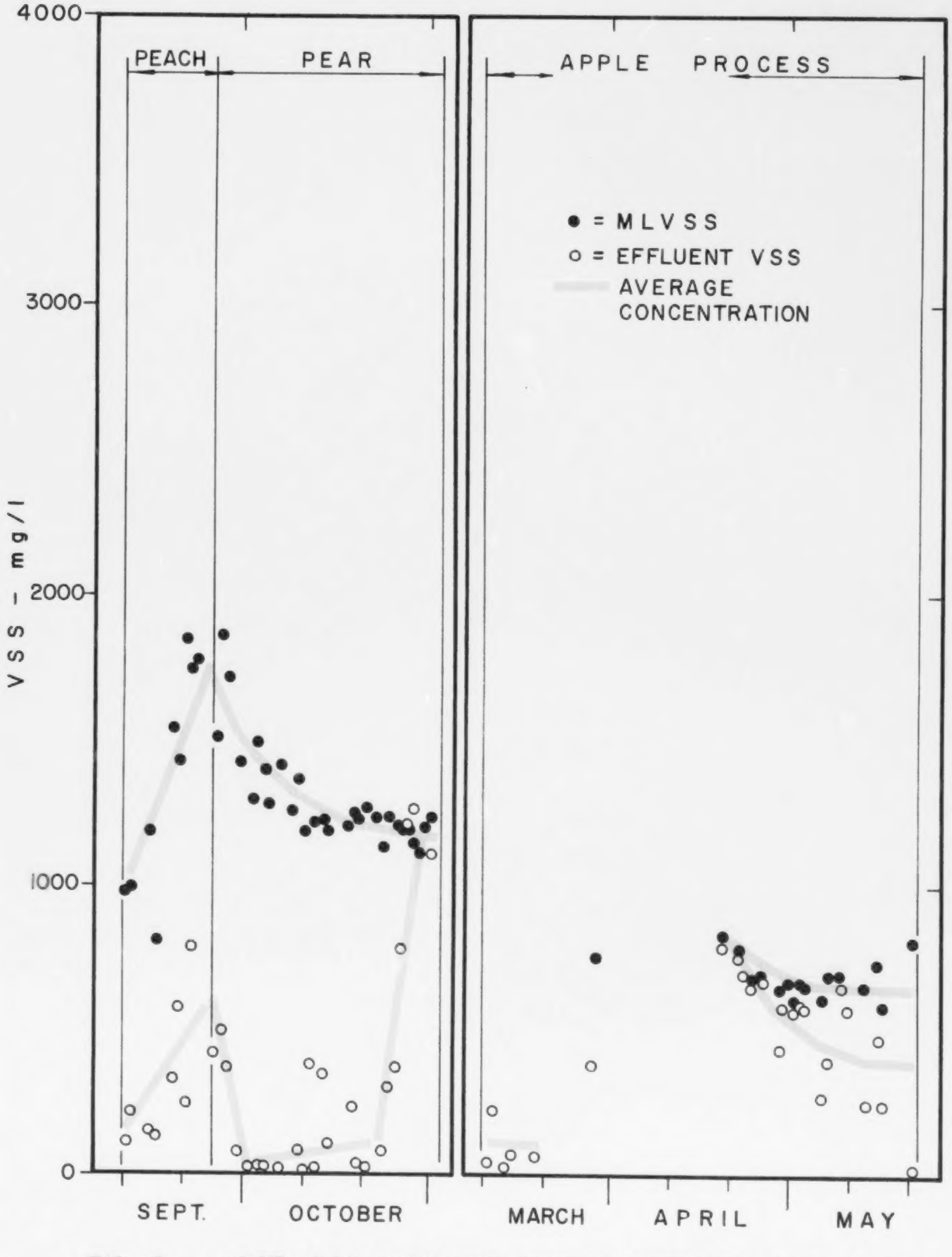

FIG. 9.— 1967-1968 ACTIVATED SLUDGE PERFORMANCE - V S S

however, that the concentration of BOD in the effluent and as can be seen from Figure 8, the concentration of COD in the effluent was quite erratic, which was due to the erratic sludge removal by the clarifier. As the solids in the system built up and the COD and BOD loading on the solids decreased, a better effluent resulted. However, it can be seen from Figure 9 that up until near the end of the pear processing season, the solids in the clarifier effluent somewhat followed the amount of solids in the aeration system and then near the end of pear processing, some sort of upset conditions resulted in a high carryover in solids into the effluent from the clarifier. During the apple processing season, that portion of processing in March showed a relatively good performance by the system, but the processing during April and May did not develop a sludge characteristic which readily separated the sludge from the water in the clarifier and a great deal of sludge carryover was experienced. A nutrient deficiency may have occurred during that time. Table III shows a summary of the activated sludge performance.

TABLE III

1967-1968 Activated Sludge Performance

	Suspended Solids-mg/l		COD-mg/l		BOD-mg/l	
Period	Influent	Effluent	Influent	Effluent	Influent	Effluent
Pear Processing	375	375	3050	490	2040	250
Peach Processing	146	370	2150	700	1810	360
Apple Processing (Mar.-Apr.-May)	47	470	1830	570	1390	130

	COD Removal-%	BOD Removal-%
Pear Processing	84	88
Peach Processing	67	80
Apple Processing (Mar.-Apr.-May)	69	91

Here again the COD removal efficiency during peach processing should not be taken too seriously due to lack of sufficient and possibly reliable data. The differences in BOD and COD removal can here again be explained by the difference between the volatile suspended solids effect in the BOD and COD tests.

Buffering Capacity and pH Control

The buffering capacity of each of the two aeration systems operated during the 1967-1968 processing season was sufficient that no pH control was necessary by external means. One of the difficulties with the system which existed during the 1966-67 season was that during pear processing the small lagoon which was in use turned quite acid and required large amounts of lime addition to keep the pH in a suitable range between 6 and 8. Figures 10 and 11 show that during the 1967-1968 season, both the aerated lagoon and the activated sludge system maintained a pH in the aeration basin consistently near 7, regardless of

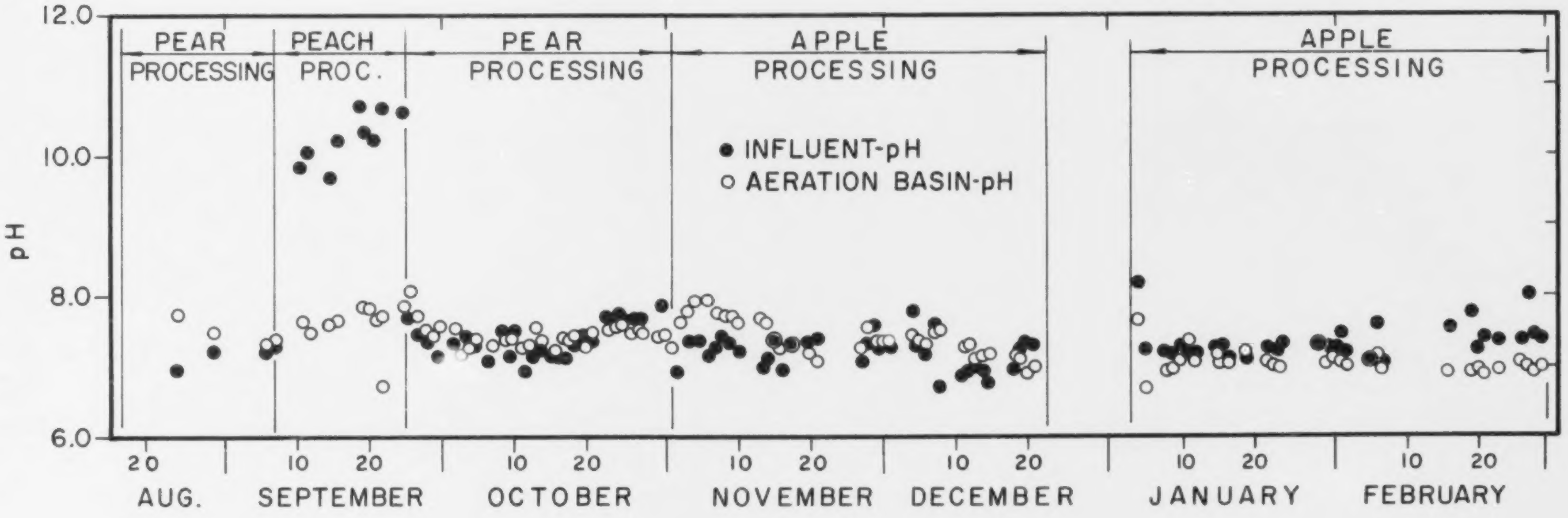

FIG. 10. — 1967-1968 AERATED LAGOON PERFORMANCE - pH

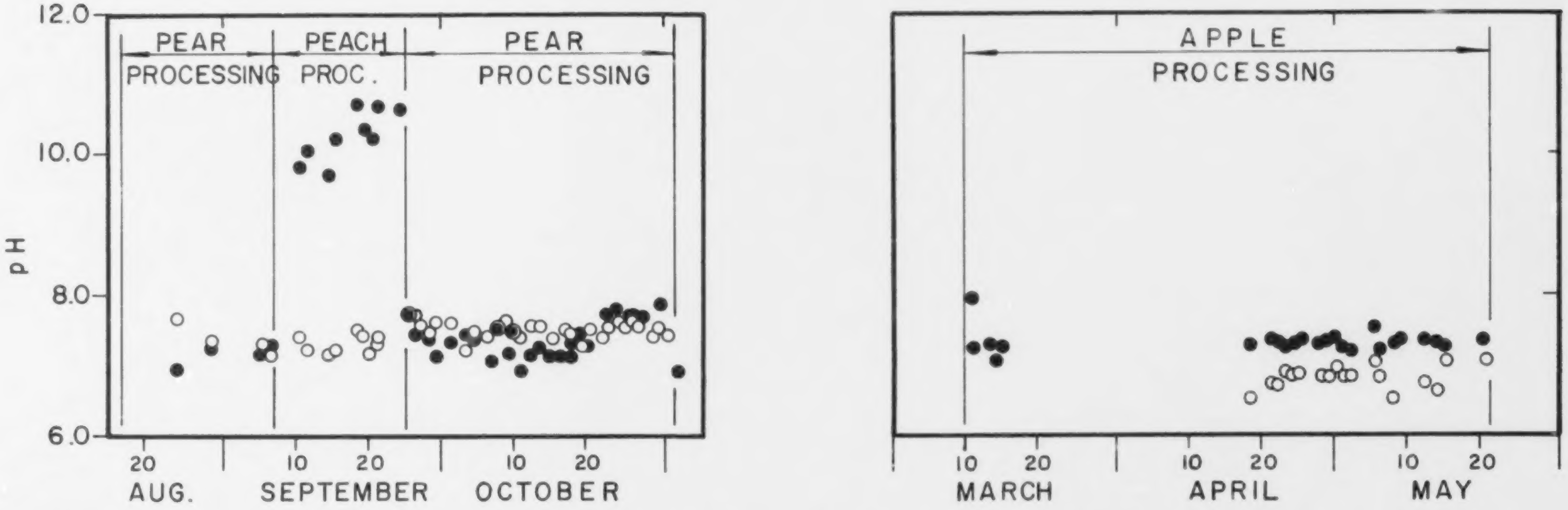

FIG. 11. — 1967-1968 ACTIVATED SLUDGE PERFORMANCE - pH

the influent pH. As it can be seen, during the pear processing and apple processing, the waste entering this system was near neutral but no acid conditions developed. During peach processing when lye peeling of the peaches is practiced, the aeration systems buffered the pH to practically the same levels as was experienced during other operational phases of the project.

Nutrient Feeding

Nutrient addition was continued throughout the processing season. A commercial fertilizer was fed in liquid form and consisted of a mixture 9-28-0 and 18-0-0. The nutrient feeding was such that the total nitrogen as N and phosphorus as P in the waste stream to the treatment systems in relation to the COD were as follows:

Product	#N/100#COD	#P/100#COD
Peaches	3.4	0.48
Pears	3.0	0.34
Apples	4.2	0.47

Sludge Settleability

The settleability of the biological sludge developed in both the aerated lagoon and the activated sludge system was not very good according to domestic waste treatment standards. However, upon studying the biological sludge settleability curves as presented in Appendix C, it can be seen that the settleability definitely improved with recycling of the sludge from the clarifier to the aeration basin as was practiced in the activated sludge system. Also the settleability of biological sludge improved with lower loading imposed by the apple processing in the aerated lagoon facility. The indication would be, therefore, that sludge settleability improves with, (1) sludge recycling and, (2) increased sludge detention time, or sludge age in the aeration system. Each of these results in a lower BOD and COD on the solids. It can be seen from the sludge settleability curves that the deterioration in the effluent quality in the latter part of October from the activated sludge system can be linked to the deterioration in sludge into the effluent. The dissolved oxygen in the lagoons was adequate during this period of time and no change in waste characteristics being fed to the lagoon was observed. The nutrient feeding was not noticeably altered during this period of time although a cumulative deficit of nutrient quantity during pear processing may have occurred.

Shutdown and Startup

As it has been indicated, there were several periods during the operating season when the cannery was not operating. This caused a complete cessation of waste feeding to the treatment system. During the down time the aerators were kept in operation so the basins would not go anaerobic. Upon resumption of processing and reintroduction of waste load to the treatment facilities, there did not appear to be any ill effects upon either waste treatment system and there didn't appear to be any decrease in efficiency of treatment.

During the down periods, the solids within the aeration basins continued to decompose via endogenous respiration. On weekends when no processing occurred in the activated sludge system, the sludge settleability improved so that improved treatment efficiency was experienced during the first part of the following week. This was due principally to the lowering of the effective BOD and COD loading.

The longer periods of no waste feeding followed by reintroduction of the waste at the breaks for Thanksgiving and Christmas didn't appear to affect the aerated lagoon as solids remained in the system and became immediately active. A lengthy shutdown was experienced in the activated sludge system during April when the sludge settleability appeared to deteriorate but no explanation is readily available. Initial startup in either system was done with the basin full of clean water and aeration begun immediately. The dilution prevented high strength discharge until the biological systems had been established satisfactorily.

Conclusions Drawn at the End of the 1967-1968 Processing Season

Conclusions at the end of the 1967-1968 processing season were:

1. The waste was definitely treatable by these aerobic processes and that a high degree of conversion of soluble organics in the waste to biological sludge was obtainable,
2. The biological sludge could be separated and recycled probably much more efficiently with a properly designed sludge removal system,
3. The design constants assumed at the beginning of the project for design of the expanded aeration system did not contain too great an error in any of the assumptions,
4. Nutrient feeding was definitely necessary and possibly had some effect on the sludge settleability,
5. The systems had adequate pH buffering capacity to level out any effects of fluctuating pH in the influent and, additionally, prevent the formation of acid conditions in the aeration system. This resulted from the adequate dilution and complete mixing.

1968 PROCESSING SEASON OPERATION

The 1968 processing season saw the installation of a new clarifier and sludge return facility. The installation of this equipment, however, did not become complete until in September which meant that nearly a month of processing had occurred prior to placement of this equipment into service. During this portion of the season, the large basin was operated as an aerated lagoon. Following the placement into service of the clarifier and sludge recycle facilities on September 12, the flow pattern was as schematically portrayed on Figure 12 and the system acted as an activated sludge system with aeration and sludge recirculation. During the period from October 16 through November 3, the return biological solids were recirculated through the small aeration basin prior to their re-entrance into the large aeration basin. This was the sludge reaeration phase of the treatment study. Following the end of pear processing on November 3 and apple processing's inception which continued through December 20 when the 1968 processing season study ended, the system was once again operated as an aeration with simple sludge recycle system. Figure 13 shows an aerial photograph of the system as it was operated during the 1968 season. At the time of this photograph, sludge recycle through the small basin was not taking place and, therefore, the mixed liquor suspended solids in the large basin was at a higher level than that in the small aeration basin.

Flow

The flow to the treatment system being studied during 1968 processing season is shown on Figure 14. On several days during the operating season a portion of the flow was bypassed and is not included on this flow chart. This occurred primarily at the very start of the season in middle and late August, during the first few days of peach processing, just prior to the placement into operation of the clarifier and sludge pumps and again at the beginning of the pear processing season which followed peach processing. These bypass periods occurred due to the necessity of lower flow going into the system during the construction operations but did not materially effect the study as it was being carried out since the bypass portion of the flow was eliminated from the calculations and testing results.

Testing Results

The performance of the treatment system during the entire season of operation is shown on Figures 15, 16, and 17 with regard to BOD and COD removal, and volatile suspended solids in the basin and in the effluent. The BOD removal through the treatment system is shown on Figure 15 with an average line also shown with the data. As it can be seen, during the aerated lagoon portion of the treatment during pear processing, approximately the same removal of BOD and COD was experienced as the previous year. During peach processing, the sludge recirculation phase was just beginning to cause MLVSS buildup and the BOD and COD removal improved during the entire peach processing area as a result of increased removal of volatile suspended solids from the effluent as the sludge settleability improved. Activated sludge treatment of pear processing waste saw excellent BOD and COD removals almost 99% of the time. The apparent increase in screened waste strength during pear processing following the peach processing is primarily a result of lowering of the process flow as

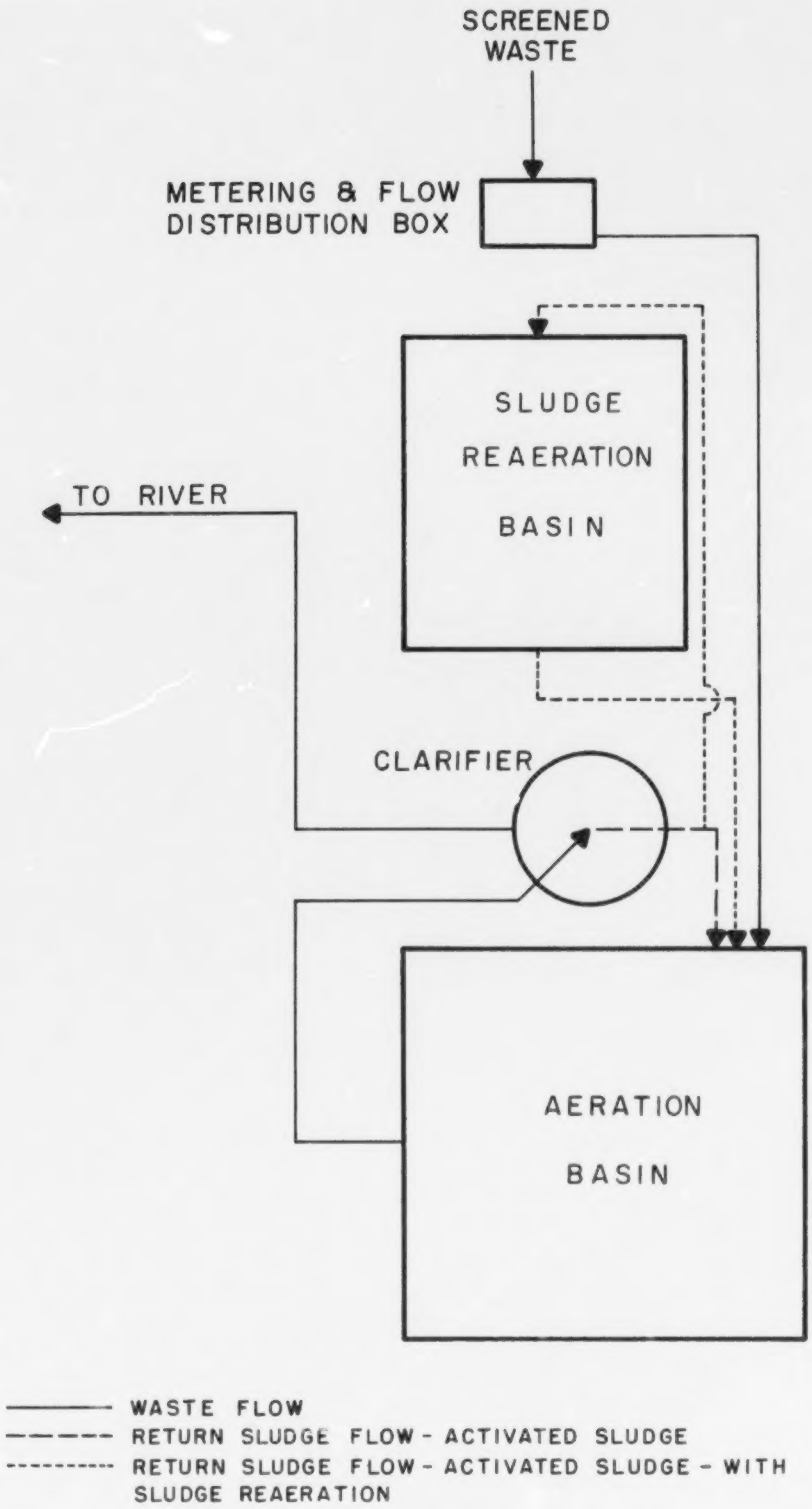
SCREENED WASTE
METERING & FLOW DISTRIBUTION BOX
SLUDGE REAERATION BASIN
TO RIVER
CLARIFIER
AERATION BASIN
WASTE FLOW
RETURN SLUDGE FLOW - ACTIVATED SLUDGE
RETURN SLUDGE FLOW - ACTIVATED SLUDGE - WITH SLUDGE REAERATION

FIG. 12. — SCHEMATIC FLOW DIAGRAM
1968 PROCESSING SEASON

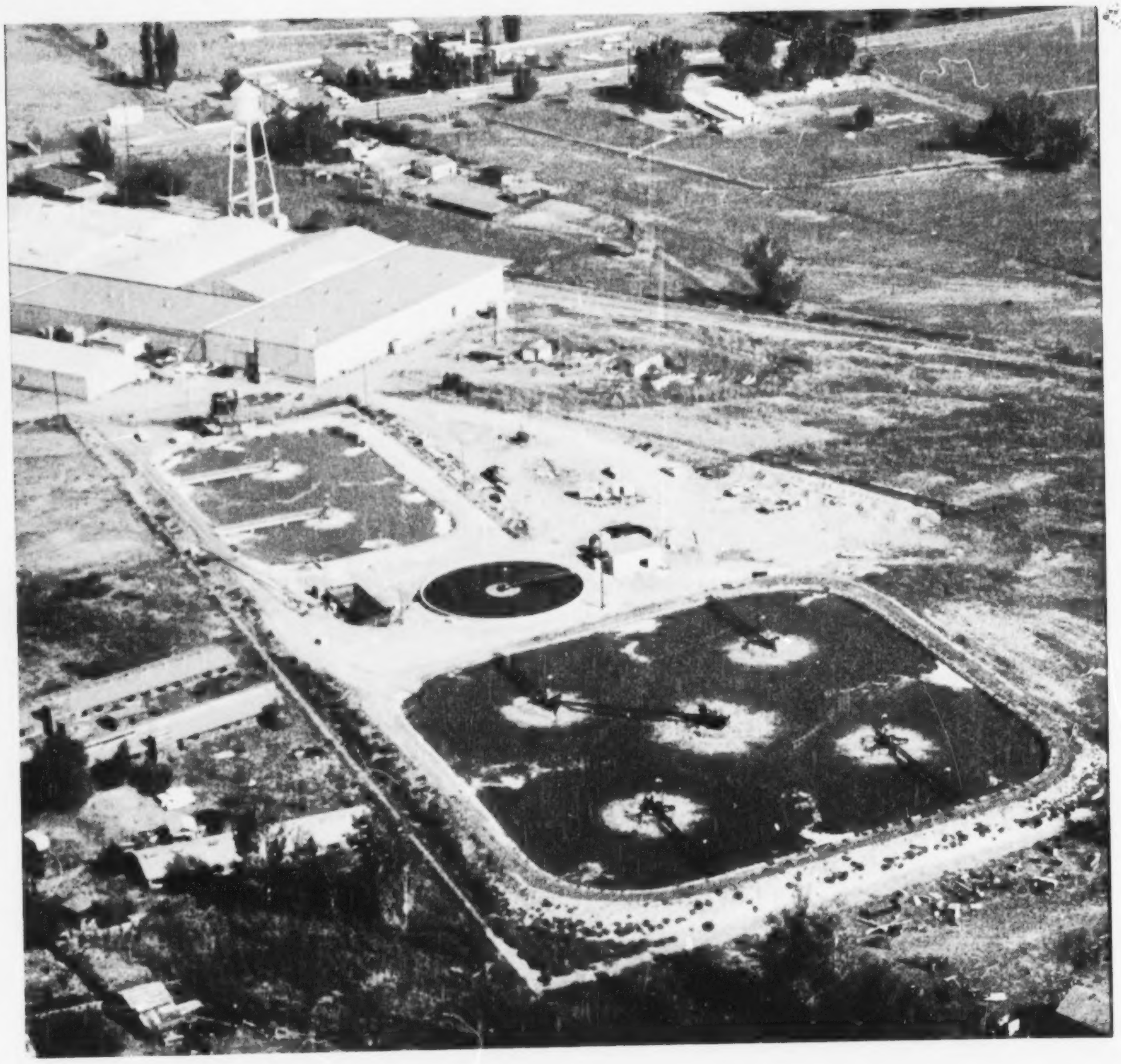

FIG. 13. — TREATMENT FACILITIES 1968 PROCESSING SEASON

AERATION BASIN, RIGHT FOREGROUND; CLARIFIER AND SLUDGE PUMP BUILDING, CENTER BETWEEN LAGOONS; SMALL LAGOON USED FOR SLUDGE REAERATION PORTION OF SEASON; SCREENING STATION AND METERING BOX BEYOND SMALL LAGOON; CANNERY BUILDINGS UPPER LEFT; LABORATORY IS SMALL BUILDING BETWEEN MAIN CANNERY BUILDINGS AND WAREHOUSE.

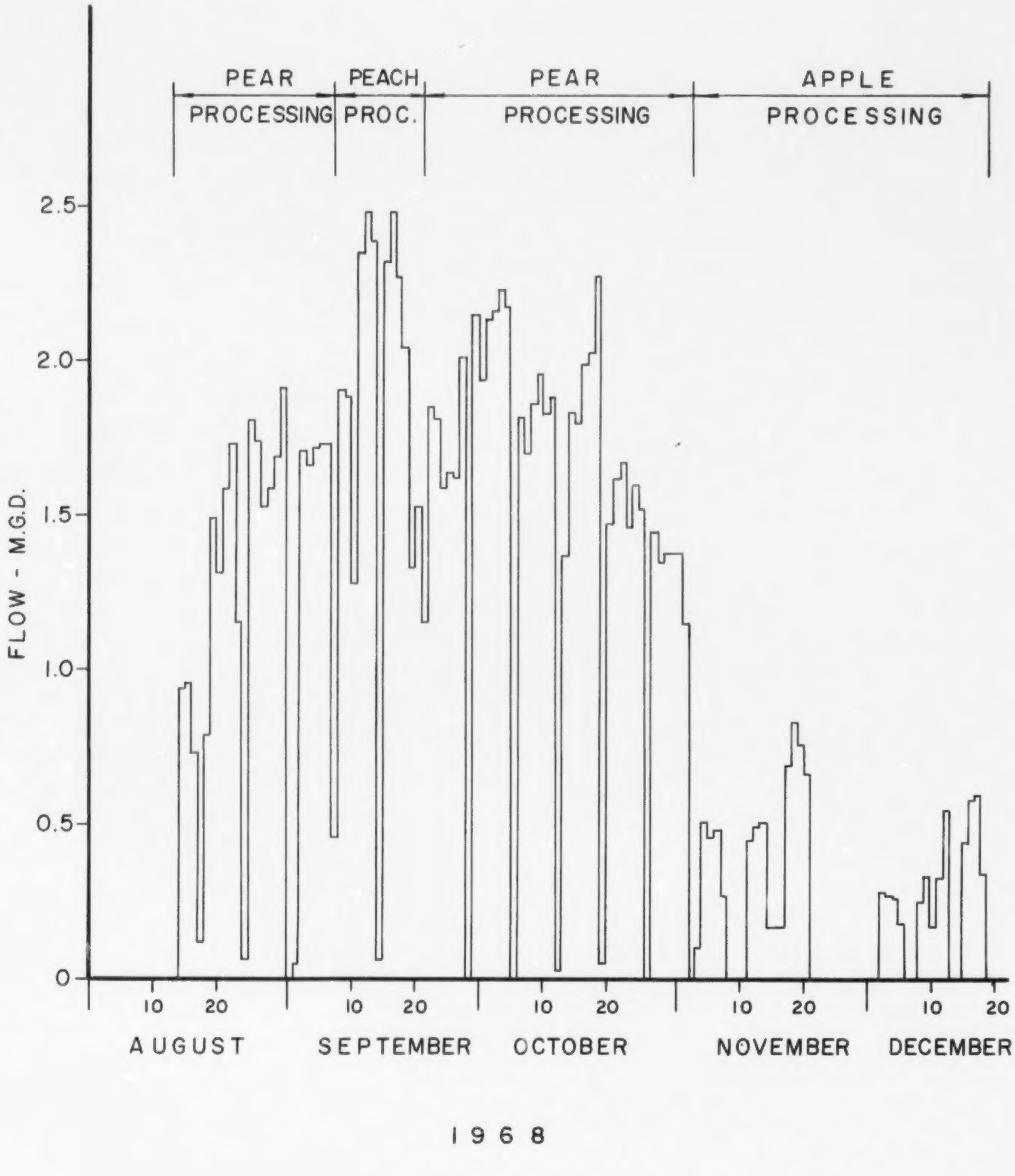

FIG. 14. — FLOW - 1968 PROCESSING SEASON

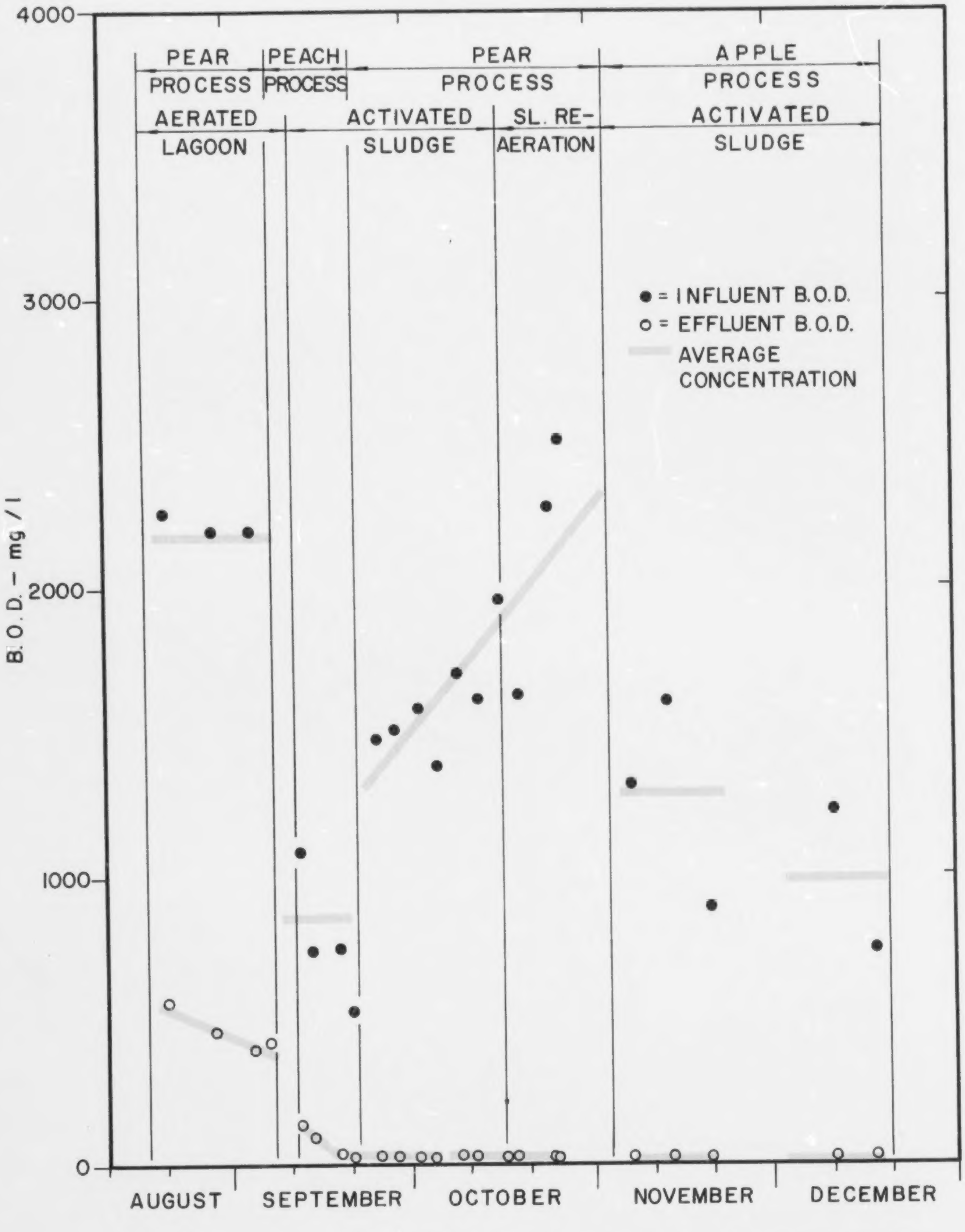

FIG. 15. — 1968 TREATMENT SYSTEM PERFORMANCE-B.O.D.

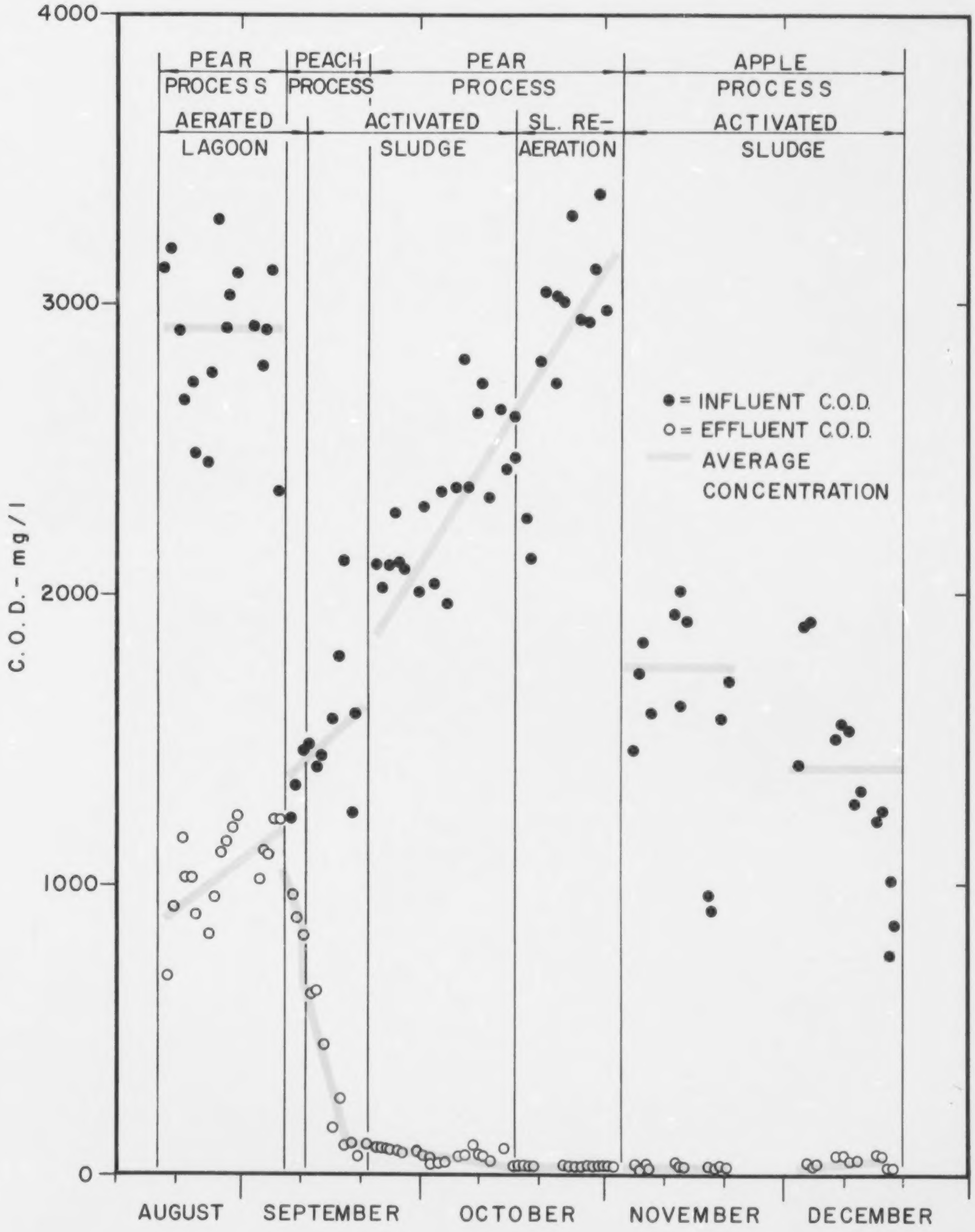

FIG. 16. — 1968 TREATMENT SYSTEM PERFORMANCE-C.O.D.

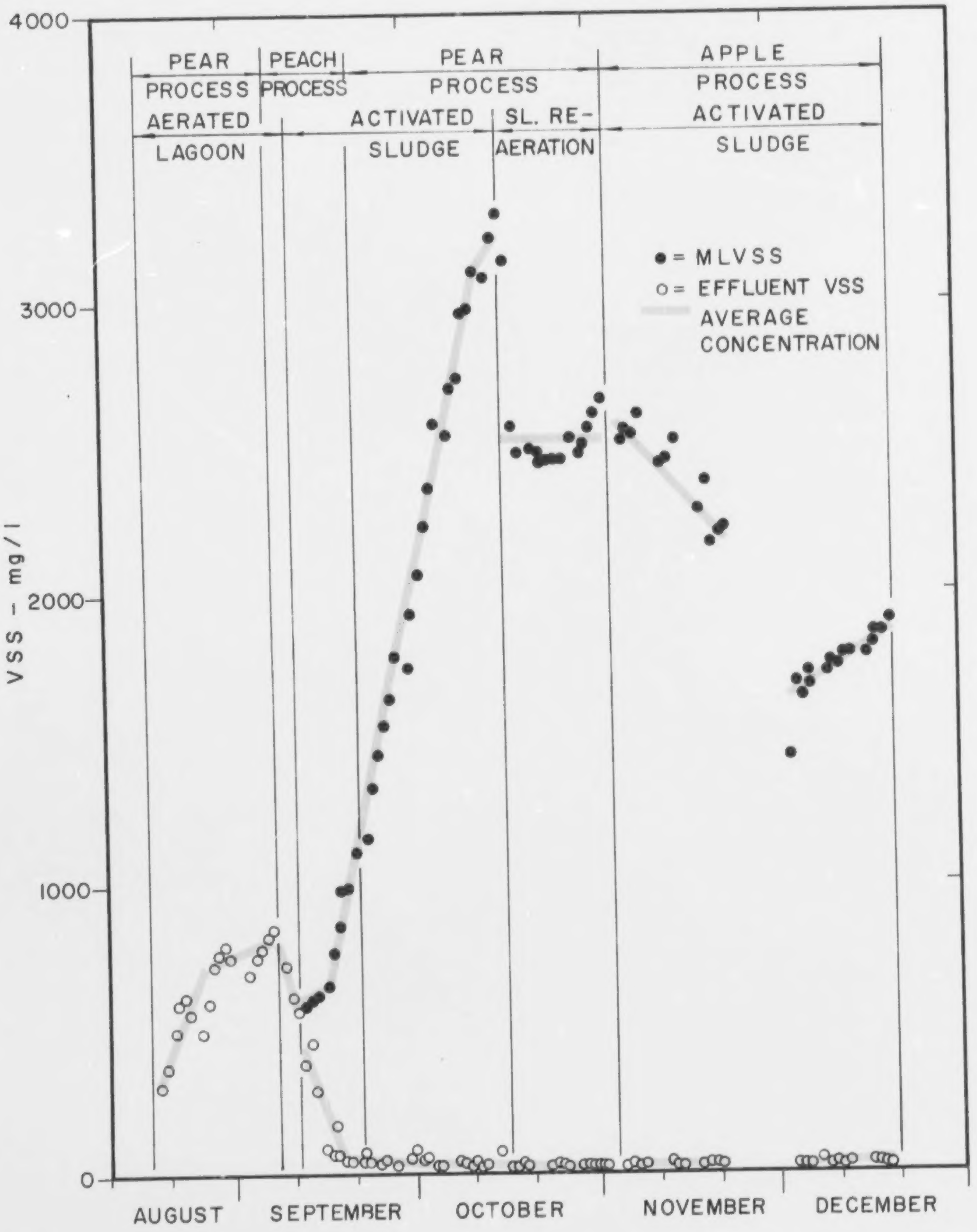

FIG. 17. — 1968 TREATMENT SYSTEM PERFORMANCE-VSS

can be seen from Figure 14 during that time, so that the actual pounds of BOD load to the system did not fluctuate greatly. During apple processing the removal of BOD and COD through the treatment system remained excellent even though the influent waste load was considerably lower. The sludge reaeration during pear processing did not show a great increase in efficiency above that of the regular activated sludge or aeration with simple sludge recycle, however, it is difficult to note changes in effiency during periods when removal efficiencies are as high as was experienced. The superiority of a well designed clarification system can be seen by the comparison of activated sludge results with the previous year. During peach processing and when the sludge recirculation to the aeration basin was operating, the sludge improved in settleability characteristics, due to the lower BOD and COD loading per unit weight of sludge and ultimately little solids carryover was experienced to raise the COD or BOD. Table IV contains a summary of treatment results.

TABLE IV

1968 Processing Season Treatment Results

	Suspended Solids-mg/l		COD-mg/l		BOD-mg/l	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Pear Processing (Aug.-Sept. 7) Aerated Lagoon	290	640	2870	1050	2080	460
Peach Processing (Sept.9-Sept.14) Aerated Lagoon & Activated Sludge Startup	110	520	1510	710	860	115
Peach Processing (Sept.16-Sept.21) Activated Sludge	110	66	1510	120	860	20
Pear Processing (Sept.23-Oct.16) Activated Sludge	290	15	2290	55	1600	9
Pear Processing (Oct.17-Nov.3) Activated Sludge with Sludge Reaeration	290	6	2910	23	2150	4
Apple Processing (Nov.5-Dec.) Activated Sludge	55	11	1500	28	1190	5

	COD Removal-%	BOD Removal-%
Pear Processing - Aerated Lagoon	63	78
Peach Processing - Aerated Lagoon and Activated Sludge	53	86
Peach Processing - Activated Sludge	92	97+
Pear Processing - Activated Sludge	97+	99+
Pear Processing - Activated Sludge and Sludge Reaeration	99	99+
Apple Processing - Activated Sludge	98+	99+

Figure 17 shows the volatile suspended solids concentration of the effluent from the treatment system and in the aeration basin separately where they were different. As it can be seen, the volatile suspended solids concentration in the effluent increased during the aerated lagoon method of treatment of the waste during pear processing and began to drop off slightly as peach processing started and prior to the inception of sludge recycling. Following the beginning of sludge removal and recycling with the clarifier and recycle pumps, the concentration of volatile suspended solids in the effluent decreased rapidly and in approximately a week began to level off with a very small amount of volatile suspended solids in the effluent. The mixed liquor volatile suspended solids concentration increased steadily following the beginning of sludge recycling due to little sludge wasting until the beginning of sludge reaeration, at which time a lower concentration of solids was carried in the aeration basin and although the total weight of solids in the system remained the same this lower concentration persisted until the beginning of apple processing, at which time the solids level began to decline due to the lower feed rate of organic material. Intentional wasting of solids in small amounts was done only once or twice during the season. There was a small continuous wastage at one bypass gate during activated sludge treatment. A larger leak was present in the sludge reaeration basin during contact stablilization treatment. Both of these leaks were measured and the sludge wastage computed for use in later computations. The results of laboratory testing during the 1968 processing season are contained in a data release covering that season [7].

pH

The pH of the treatment system as operated in the 1968 processing season exhibited much the same characteristics as were seen during the 1967-1968 season. The aeration system displayed the ability to buffer the pH of the contents within a very narrow range and the range which is considered acceptable for biological treatment regardless of the incoming waste pH although no acid wastes were discharged to the system. During peach processing the lye peel practice resulted in highly alkaline waste being introduced to the aeration basin which had no adverse effect on the aeration basin contents. Figure 18 shows the pH of the influent and of the aeration basin during the 1968 processing season.

Nutrient Feeding

During the 1968 processing season, the nutrient feeding schedule was changed somewhat from that practiced during the 1967-1968 season. Nitrogen and phosphorus in the form of 9-28-0 were fed to the system to provide the amount of phosphorus required. The additional nitrogen required was fed in the form of 29.1-0-0 which contained predominately NH_3 nitrogen and a smaller proportion of NO_3 nitrogen than the 50% of each contained in the 18-0-0 fed during the previous season.

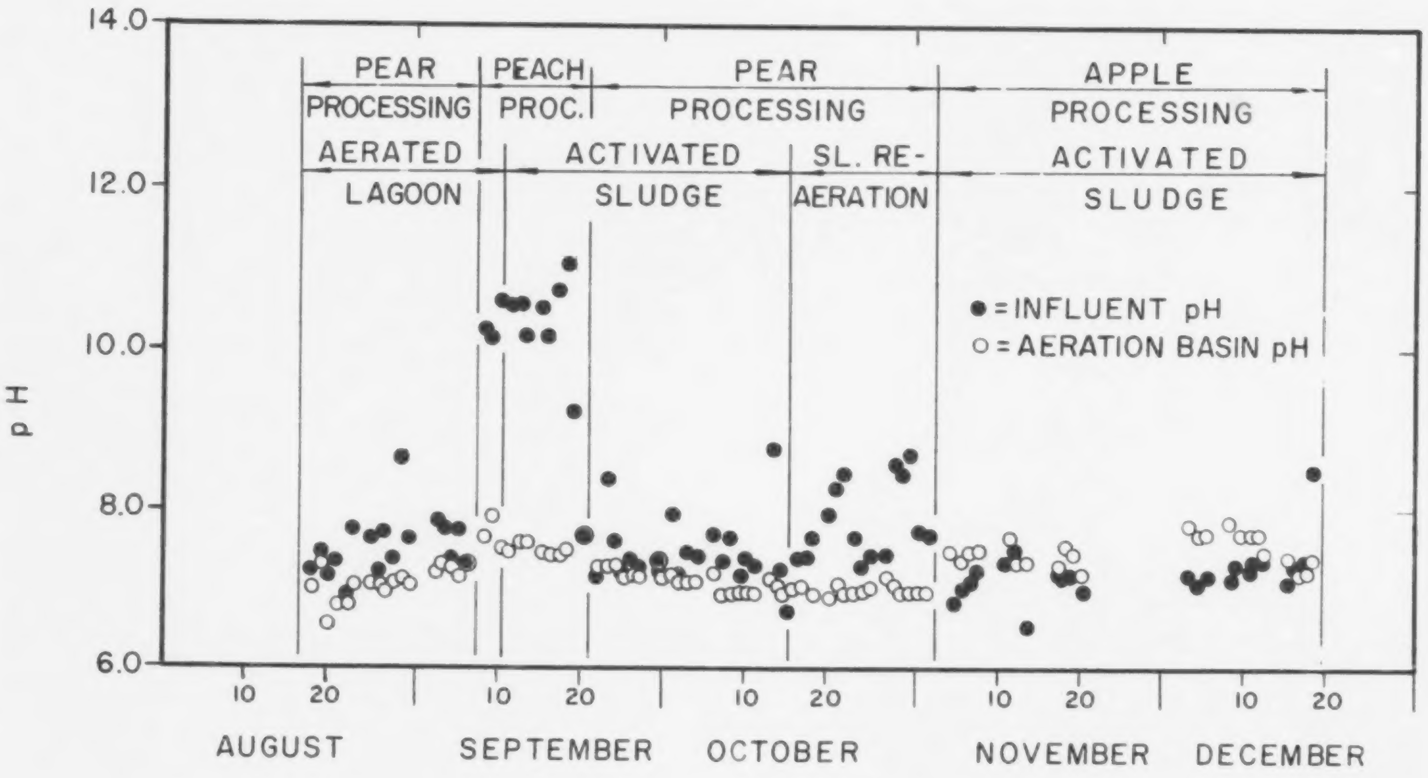

FIG. 18. — 1968 TREATMENT SYSTEM PERFORMANCE - pH

The nutrient fed during this season was such that the nitrogen and phosphorus in the influent to the treatment system were in relation to the COD as shown following:

Date	Product	#N/100#COD	#P/100#COD
Aug. 19-31	Pears	4.2	0.49
Sept. 3-7	Pears	3.9	0.80
Aug. 9-20	Peaches	5.3	1.13
Sept.21-Nov.2	Pears	3.6	0.73
Nov. 5-20	Apples	2.1	0.47

The reason for the reduction in nutrient feed ratic during apple processing from what had been previously practiced was the amount of residual nutrient in the treatment system as compared to the influent organic load in the apple processing waste and the nutrient being released from the existing biological sludge as it was broken down by endogenous respiration.

Sludge Settling Characteristics

The settling curves gathered during the 1968 processing season are contained in Appendix C following those gathered during the 1967-1968 processing season. As can be seen from these settling curves, the sludge from the aerated lagoon treatment settled rather well initially and then decreased slightly in settleability prior to the inception of sludge recycling. It must be noted here however, that considerable suspended solids remained in the supernatant in the form of "deflocculated" sludge during this period. Following the beginning of sludge recycling, the settling curves did not indicate very good settling characteristics although the settled suspended solids were increasing steadily following the beginning of sludge recycling. The settling characteristics of the sludge became somewhat better as the amount of biological solids in the system increased and the COD loading on the system therefore decreased. In addition, the supernatant began to contain less and less deflocculated sludge as the MLSS concentration increased. By the time of the sludge reaeration phase of treatment, the settleability became quite acceptable as compared to previously, and the supernatant contained nearly no suspended solids although the rate of settling still did not nearly equal that normally experienced in a domestic activated sludge system where it is expected to get nearly complete settling within the period of approximately an hour and little settling following that. The sludge settling characteristics during December more nearly followed that which would be expected from a domestic treatment activated sludge except for not achieving the degree of compaction normally observed there. The supernatant continued to contain nearly no suspended solids. The loading rate of COD on the volatile suspended solids during this time was quite low however.

The clarity of the effluent from the clarifier was very good during the late pear processing season as can be seen on Figure 19 and continued throughout the rest of the 1968 season.

Startup

Startup of the activated sludge system from an aerated lagoon resulted in several days of operation when considerable solids were lost over the clarifier weir because of poor settleability. The startup of the aerated lagoon system resulted in an effluent BOD and COD which started out at approximately the dilution values. The BOD decreased while the COD increased with the development of active organisms. Future startups will probably combine these two characteristics and it may take two weeks of operation before establishment of optimum treatment at the beginning of each processing season. Short duration shutdowns when the sludge mass can be retained in an active state should not result in effluent deterioration. This was observed during the Thanksgiving shutdown.

DISCUSSION

WASTE LOAD

The cannery on which this study was run processes fruit grown in the Yakima Valley area into canned product. During each season, the cannery processed pears and peaches during separate seasons and concurrently canned tomato juice and purple plums. Following the end of the pear processing season, approximately the first of November, apples were processed into applesauce, apple slices and apple rings on through the winter months. The 1968 season saw a reduced apple crop in the local area and on approximately the 20th of December the apple processing season ended. Although some apples came out of storage later during the winter, their quantity was not sufficient for the study to continue and the study was ended in December, 1968.

During the study, raw waste flows from the process were recorded and tested for BOD and COD content following screening over 20 mesh vibrating screens. Production figures were available from the cannery during the processing season and unit waste load contributions have been computed therefrom. The capacity of the cannery for both pear and peach processing is approximately 250 tons of raw product per two shift day. Approximately 150 tons of tomatoes can be processed during a two shift day concurrently but this figure is seldom reached due to the availability of raw product, and the processing day is adjusted according to the raw product available. Approximately 50 tons of plums can be processed concurrently with the peaches and pears on a two shift basis. The cannery's capacity for apple processing depends on the products produced but is generally approximately 100 tons per two shift day.

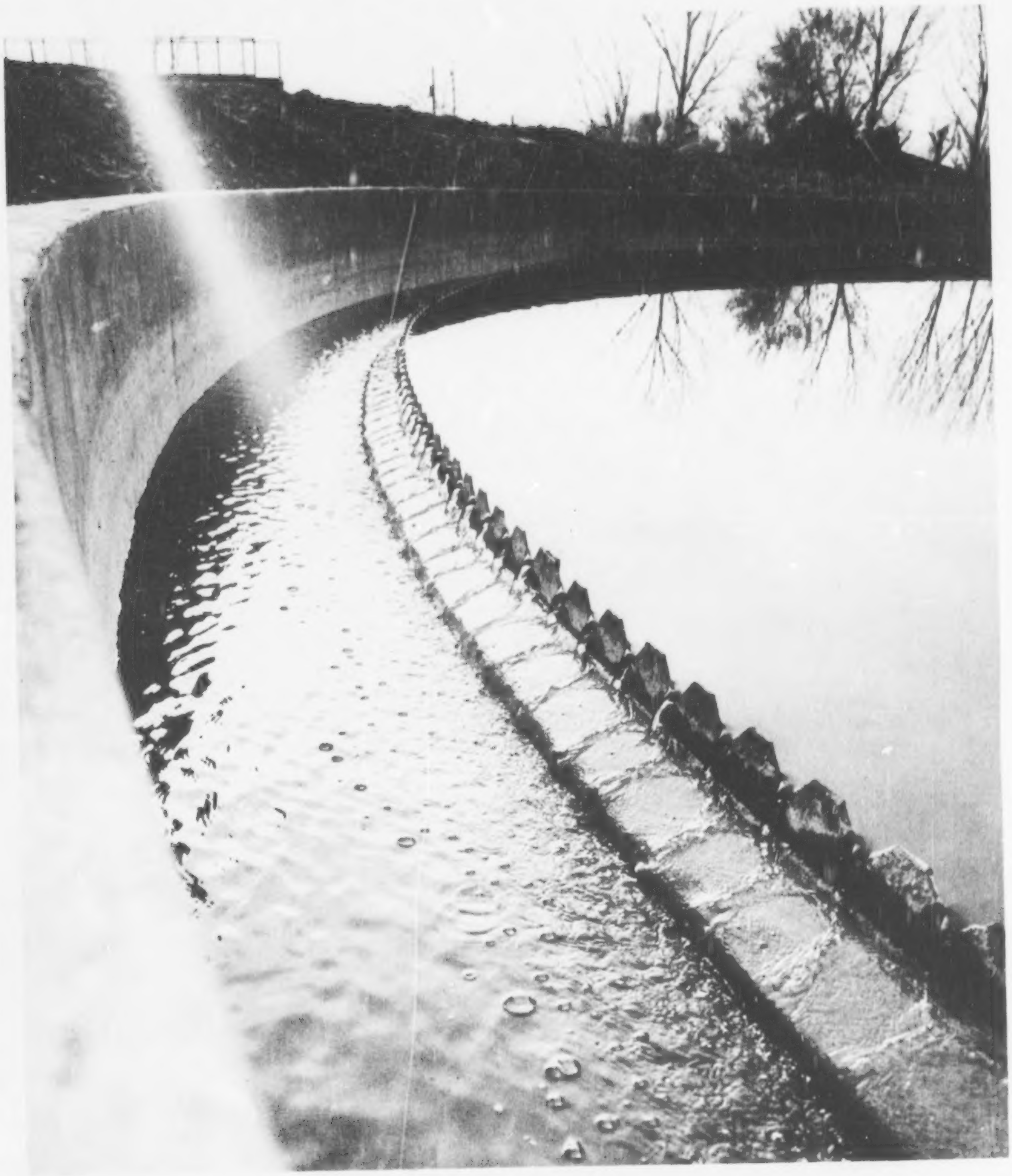

FIG. 19. — CRYSTAL CLEAR CLARIFIER EFFLUENT DURING 1968 PROCESSING SEASON.

The unit waste loads contributed during the processing seasons have been computed and averaged. The unit waste flows during process and the standard deviations in the flow have been determined to be approximately as follows:

Product	Flow - gal/ton Raw Product	Standard Deviation gal/ton Raw Product
Pears	5800	800
Peaches	7500	1000
Purple Plums	7000	1000
Tomato Juice	3200	500
Apples	8200	2600

The chemical oxygen demand (COD) contribution of the products processed were as follows:

Product	COD - #/Ton Raw Product	Standard Deviation #/Ton Raw Product
Pears	105	13
Peaches	98	15
Purple Plums	95	15
Tomato Juice	Negligible Compared to concurrent products being run	
Apples	71	18

The biochemical oxygen demand (BOD) contribution during the waste study period was as follows:

Product	BOD - #/Ton Raw Product	Standard Deviation #/Ton Raw Product
Pears	78	10
Peaches	66	10
Purple Plums	64	10
Tomato Juice	Negligible Compared to other products being processed	
Apples	53	14

The ratio of BOD concentration in the raw screened waste compared to the COD in the raw screened waste varied somewhat between products. On the 1967-1968 processing samples, the BOD's were run on canned preserved samples in many instances. The correlation between BOD and COD on the fresh samples from these canned samples was not different from the correlation between BOD and COD, both taken on the raw samples for other times during that season and during the 1968 season. The correlation was greater than 80% on the "t" series between the two sets of data. The BOD to COD ratios in the raw waste among the separate products during this study were as follows:

Product	BOD over COD	Standard Deviations
Pears	0.74	0.09
Peaches	0.67	0.10
Apples	0.75	0.07

The quantities of nutrient in the raw waste are insufficient for biological treatment according to standards generally accepted. The amount of nitrogen and phosphorus in the raw waste stream varied slightly between products processed. The nitrogen and phosphorus are computed as a ratio to the BOD and COD concentration in the waste stream to be more meaningful. Prior to any nutrient addition, the nitrogen and phosphorus in the raw waste following screening were as follows:

Product	$\frac{N}{BOD}$	$\frac{N}{COD}$	$\frac{P}{BOD}$	$\frac{P}{COD}$
Pears	0.006	0.004	0.0012	0.0009
Peaches	0.011	0.007	0.0027	0.0016
Apples	0.0023	0.0017	0.0010	0.0008

COST OF TREATMENT

Cost of treatment consists of the cost of the construction of facilities and the annual cost of operation and maintenance. A breakdown of each of these costs as experienced to date on the project are included in Appendix A, Tables A-1, and A-3. Table V contains a summarization of these costs included in the appendix and, in addition, breaks down the construction cost of facilities into an annual charge based on amortization over 20 years, assuming that money for construction was borrowed at 7% interest. An average of $40,000 for the annual cost of operation and maintenance was taken and a $5,000/year cost of major improvements and equipment replacement and repair was assumed to add to the $51,300/year annual amortization charge for construction. This makes a total annual charge of $96,300 per year for the treatment facility.

During the 1967 season, approximately 2,077,000 pounds of COD were in the screened waste going to the waste treatment system. During the same season, approximately 1,523,000 pounds of BOD were in the screened waste. The 1968 processing season saw approximately 1,997,000 pounds of COD and 1,464,000 pounds of BOD in the screened waste going to the treatment system. Based on an average of 2,000,000 pounds of COD and 1,500,000 pounds of BOD per operating season, the cost of treatment of the waste is approximately 4.8¢ per pound of COD and 6.4¢ per pound of BOD discharged to the waste treatment facility. Based on the treatment cost per pound of COD the treatment cost per ton of raw product for pears, peaches, purple plums, and apples is also shown on Table V.

TABLE V

COST OF WASTE TREATMENT - TOTAL SYSTEM

Total Cost of Construction	$543,158
Amortization Factor 20 years @ 7% Interest	0.0944
Annual Cost of Construction	51,300
Annual Cost of Operation & Maintenance	40,000
Approximate Annual Major Improvement or Equipment Replacement & Repair	5,000
Annual Cost of Waste Treatment	$ 96,300

Annual Waste Load $COD = 2 \times 10^6 \#$
$BOD = 1.5 \times 10^6 \#$

Approximate Cost of Treatment	$0.048/#COD Added 0.064/#BOD Added
Pears	$5.00/Ton Raw Product
Peaches	4.70/Ton Raw Product
Purple Plums	4.50/Ton Raw Product
Apples	3.40/Ton Raw Product

Since aerated lagoon treatment provides only 70 to 80 percent reduction in BOD and leaves a high suspended solids load in the effluent, whereas activated sludge treatment with or without sludge reaeration provides nearly "complete biological or secondary treatment", it would seem advisable to compare the alternatives more thoroughly.

Taking the costs as presented in Appendix A and choosing only those applicable as a basis for estimating, a cost figure can be gotten for each of the three methods of treatment employed. Table VI contains estimates of treatment costs for the waste load for each of the three treatment methods separately. The construction costs include an increase of 10 percent above what was experienced at Snokist in an attempt to offset inflation and engineering design and construction services at a rate of 12 percent. No nutrient savings are considered between treatment methods but a saving in both power cost and operation and supervision costs are considered for the aerated lagoon operation over the other two.

TABLE VI

ESTIMATED COSTS OF SEPARATE METHODS OF TREATMENT

		Activated Sludge	
	Aerated Lagoon	Without Sludge Reaeration	With Sludge Reaeration
Construction Costs	$205,000	$470,000	$557,000
Annual Cost of Construction (20 years @ 7% Interest)	19,400	44,400	52,600
Power Cost	7,000	10,000	10,000
Nutrient Chemicals	10,500	10,500	10,500
Operation and Supervision	6,000	12,500	12,500
Maintenance, Labor & Materials	1,500	2,000	2,000
Laboratory Supplies	1,500	2,500	2,500
Major Repairs & Improvements	3,000	5,000	5,000
Annual Cost of Treatment	$ 48,900	$ 86,900	$ 95,100
Assumed % COD Removal	70%	90%	90%
COD Removal Costs = $\frac{\text{Annual Cost}}{2\text{x}10^6\#\text{CODx\% Rem.}}$	$ 0.035/ #COD Rem.	$ 0.048/ #COD Rem.	$ 0.053/ #COD Rem.
Assumed % BOD Removal	80%	95%	95%
BOD Removal Costs = $\frac{\text{Annual Cost}}{1.5\text{x}10^6\#\text{BODx\% Rem.}}$	$ 0.041/ #BOD Rem.	$ 0.061/ #BOD Rem.	$ 0.067/ #BOD Rem.

As can be seen, the aerated lagoon provides a considerable cost saving over the nearly complete biological treatment offered by the activated sludge or activated sludge with sludge reaeration. Of course, the aerated lagoon treatment is probably not adequate to permit release of the waste into the environment but would lower the load considerably on a municipal treatment plant if the cannery discharged to a municipal sewage system. It could make lagooning in facultative lagoons following the aerated lagoon feasible in more remote locations with adequate land availability. The aerated lagoon effluent contains suspended solids in excessive amounts as compared to domestic waste and this would have to be taken into consideration.

An additional cost factor is not included in Table VI for either of the complete secondary treatment schemes. This is the cost of waste sludge disposal, since this project did not adequately evaluate costs along this line. The thickening by equipment included in this project will probably be good to only 3 to 4 percent solids on a dry weight basis. Their further dewatering and subsequent disposal or disposal in this relatively wet state needs further investigation.

A comparison can be made between costs estimated here and those estimated in a recent publication of the California Water Resources Control Board concerning cannery waste treatment [8]. In that publication cost estimates were made for treatment of a waste much weaker than those experienced in this study but by adjusting flows the cost estimates should be comparable. For aerated lagoon treatment the California publication has estimates for an 8 MGD flow with a COD of 450 mg/l. This would be equivalent to 1.44 MGD at 2500 mg/l or roughly what was experienced on this project. They indicate (p. 154) that roughly 5 days detention time is required to achieve 80 percent BOD removal but taking this detention time at higher concentration and less flow would decrease the capital cost of construction to approximately what they have computed for 1.2 days detention time. The annual O & M costs for 80 percent removal would not change.

Capital Cost	$222,600
20 Years at 7%	21,000
Annual O & M Costs	68,130
Total Annual Costs	$ 89,130

As can be seen, it is primarily in the annual O & M estimate where the cost estimated differs with that estimated from this project (see Table VI).

The estimate for activated sludge treatment made by the California Water Resources Control Board Report can be taken nearly directly for the 8 MGD flow at 450 mg/l COD since flow has less impact on the capital expenditure. However, the figures for 89.5% BOD removal efficiency will be used for comparison.

Capital Cost	$550,000
20 Years at 7%	51,900
Annual O & M Costs	58,400
Total Annual Costs	$110,300

The figure derived is slightly higher in each capit 1 cost and O & M than the costs estimated from the experiences of this project (see Table VI).

SUBSTRATE REMOVAL

Substrate, or soluble COD and BOD, removal from the waste stream was presented in theory earlier and equations (1) and (2) set up to describe the function. Equation (2)

$$R = fs \qquad (2)$$

is the most easily evaluated equation since it involves a straight line relationship with the origin at the axis when R and s are plotted. Considerable data was collected on substrate removal rate and remaining substrate concentration during the course of this study. Considerably more data on COD removal rate and soluble COD remaining was collected than was data on BOD removal rate and BOD remaining. Figures 20 through 26 show the COD removal rate versus the soluble COD remaining in the effluent. Since each of the aeration systems used was considered a completely mixed system, the soluble COD in the effluent was the COD in the aeration basin upon which the organisms had to react. These figures are divided up according to product being processed and the temperature of the aeration basin during the period which data was collected. As can be seen, the slopes of the lines drawn through the axis of the plot and through the data at the median data point varies between the plots. It can be observed that the slopes of these lines vary approximately according to the temperature of the aeration basin with the exception of the pear processing activated sludge with sludge reaeration or contact stabilization as shown on Figure 23. This contact stabilization system would not be expected to follow the same reaction kinetics in this respect as the completely mixed systems without sludge reaeration prior to reintroduction into the aeration system, since the entire biological mass does not have the same substrate level from which to continuously work. The entire VSS in the system was used to compute the COD removal rates. All of the data on Figure 20 was collected during aerated lagoon operation. Data on Figure 24 was collected during aerated lagoon and activated sludge treatment of the waste. Figures 21, 22, 25, and 26 contain data from activated sludge operation.

Figure 27 contains a plot of the slope as plotted on the previous figures 20 through 26 versus the temperature in the aeration basin in degrees centigrade. As can be seen, a straight line plot can be obtained when the COD removal coefficient is plotted on semilogarithmic scale. From Figure 27 equation (10) which is a form of the Arrhenius equation [2] can be derived which establishes the COD removal rate for this fruit processing waste in a completely mixed aeration system. This formula ignores differences between products being processed.

$$f_T = 0.017 \times 1.16^{(T-20)} \qquad (10)$$

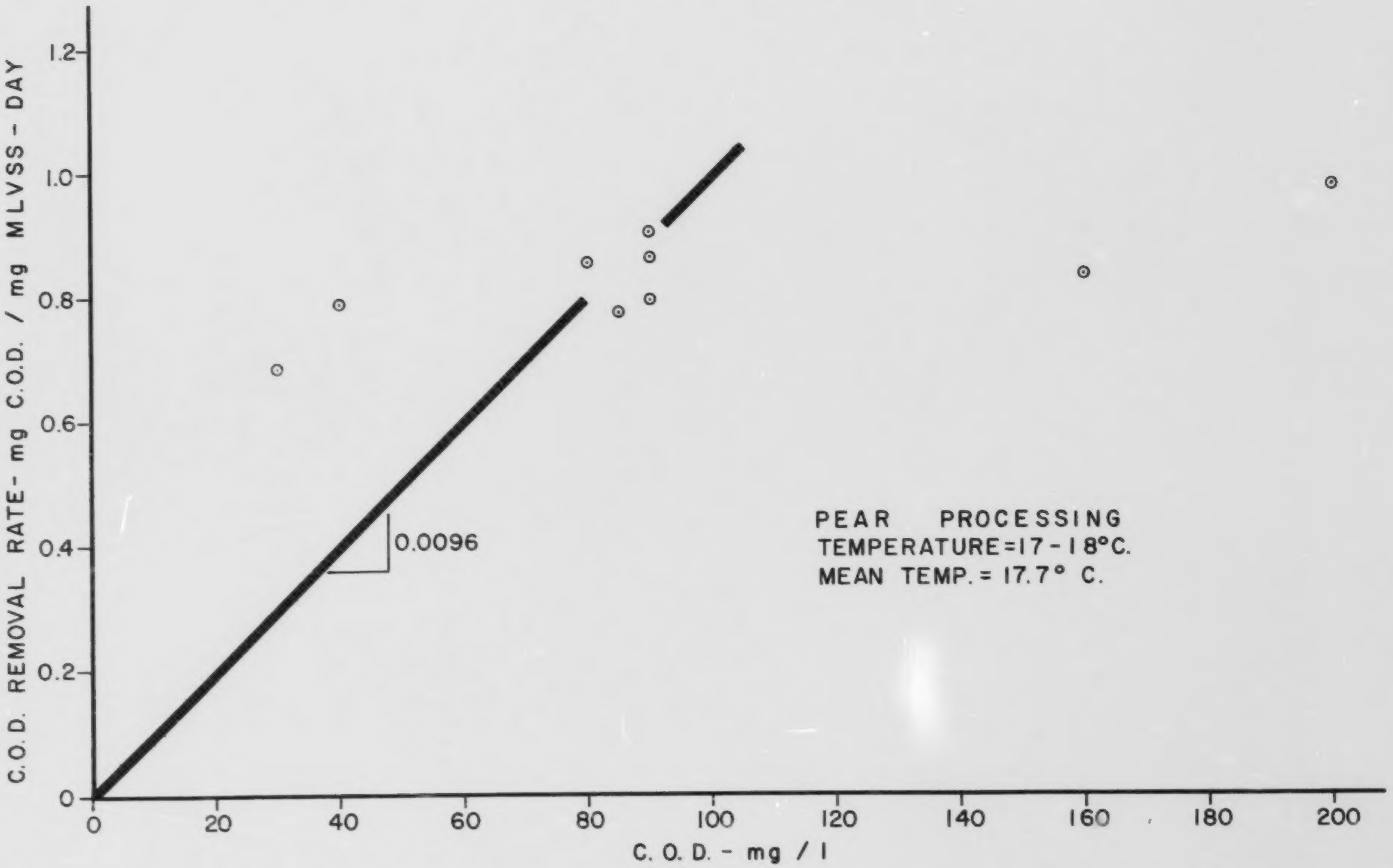

FIG. 20. — C.O.D. REMOVAL RATE VS CONCENTRATION

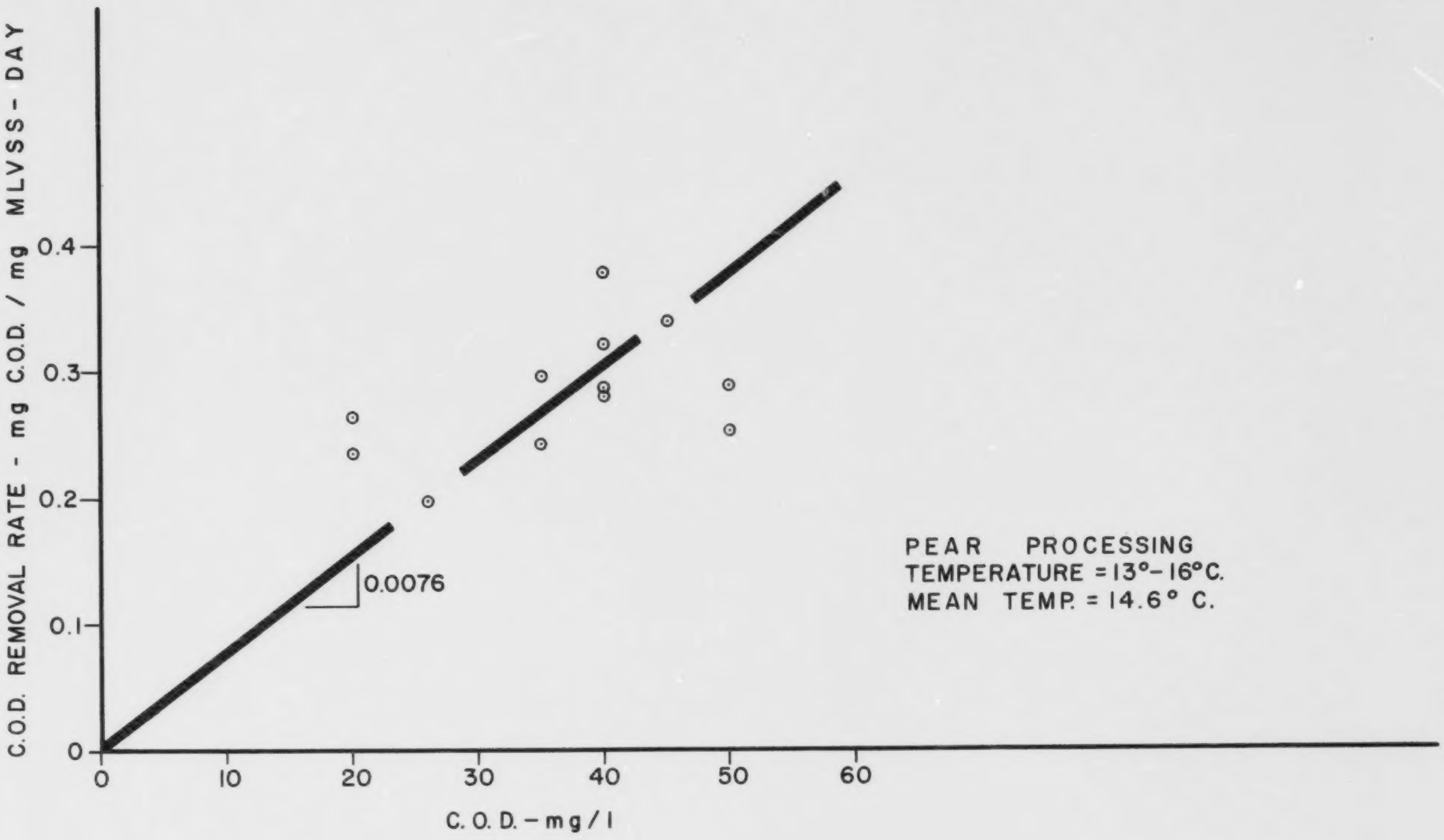

FIG. 21. — C.O.D. REMOVAL RATE VS CONCENTRATION

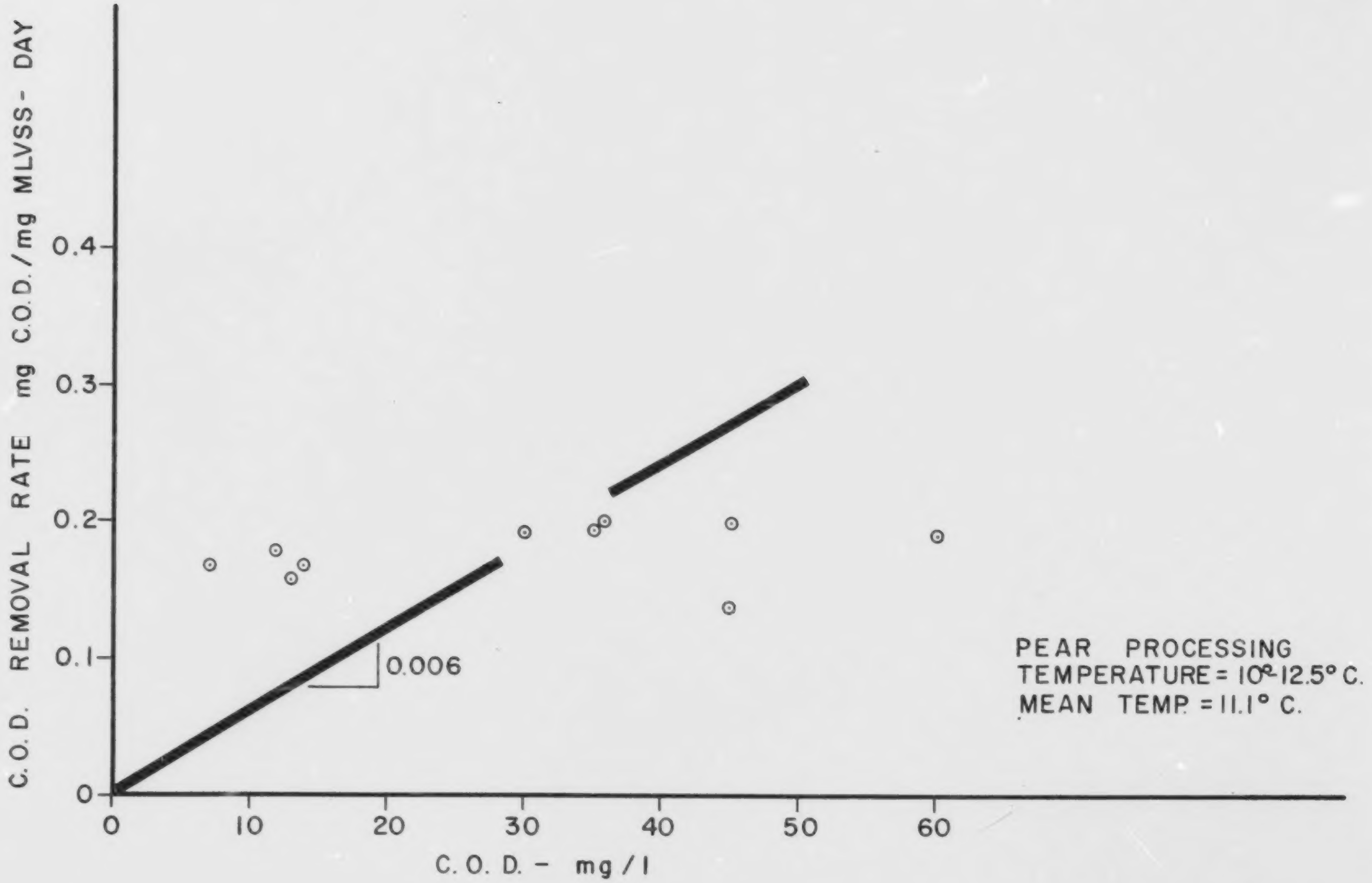

FIG. 22. — C.O.D. REMOVAL RATE VS CONCENTRATION

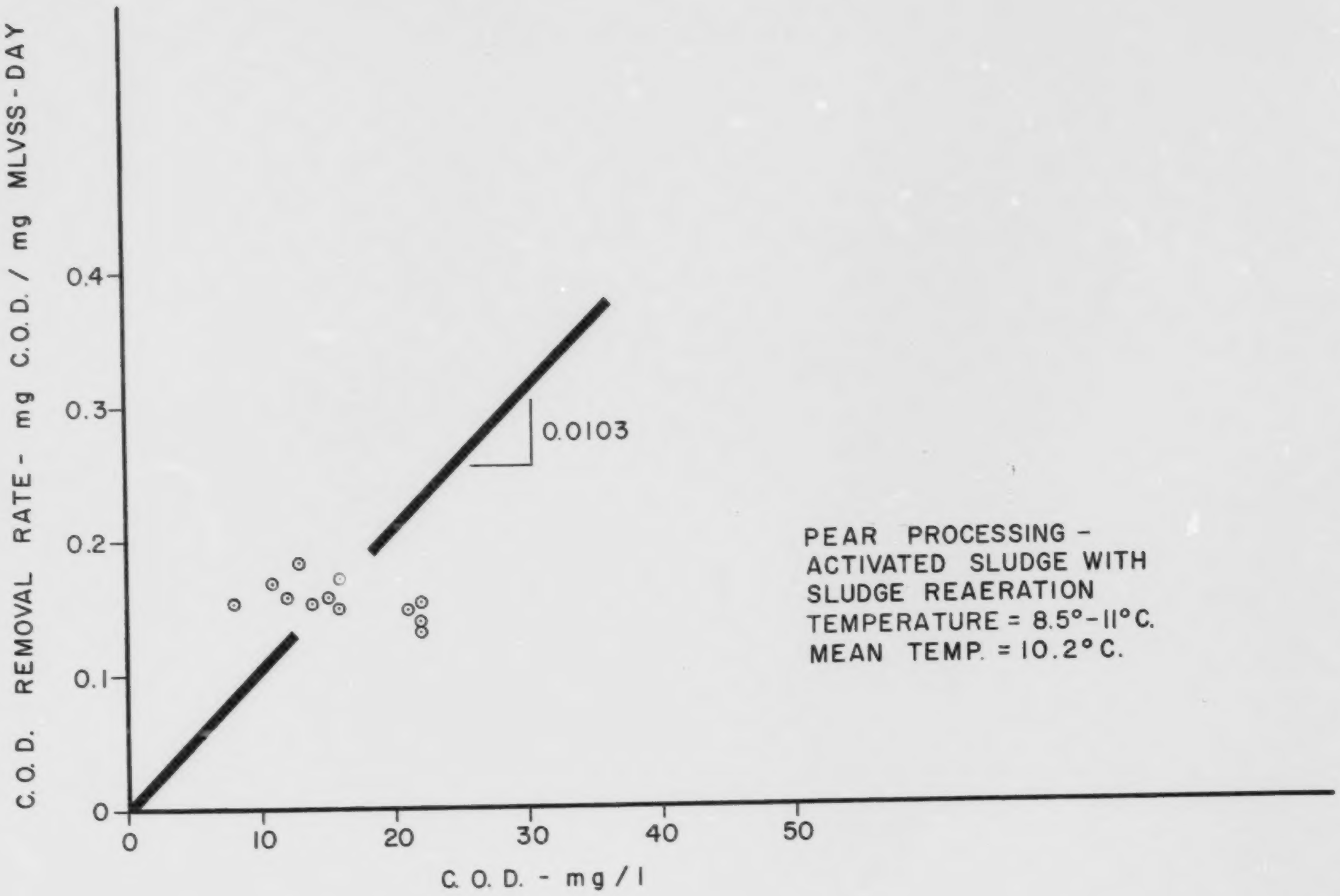

FIG. 23. — C.O.D. REMOVAL RATE VS CONCENTRATION

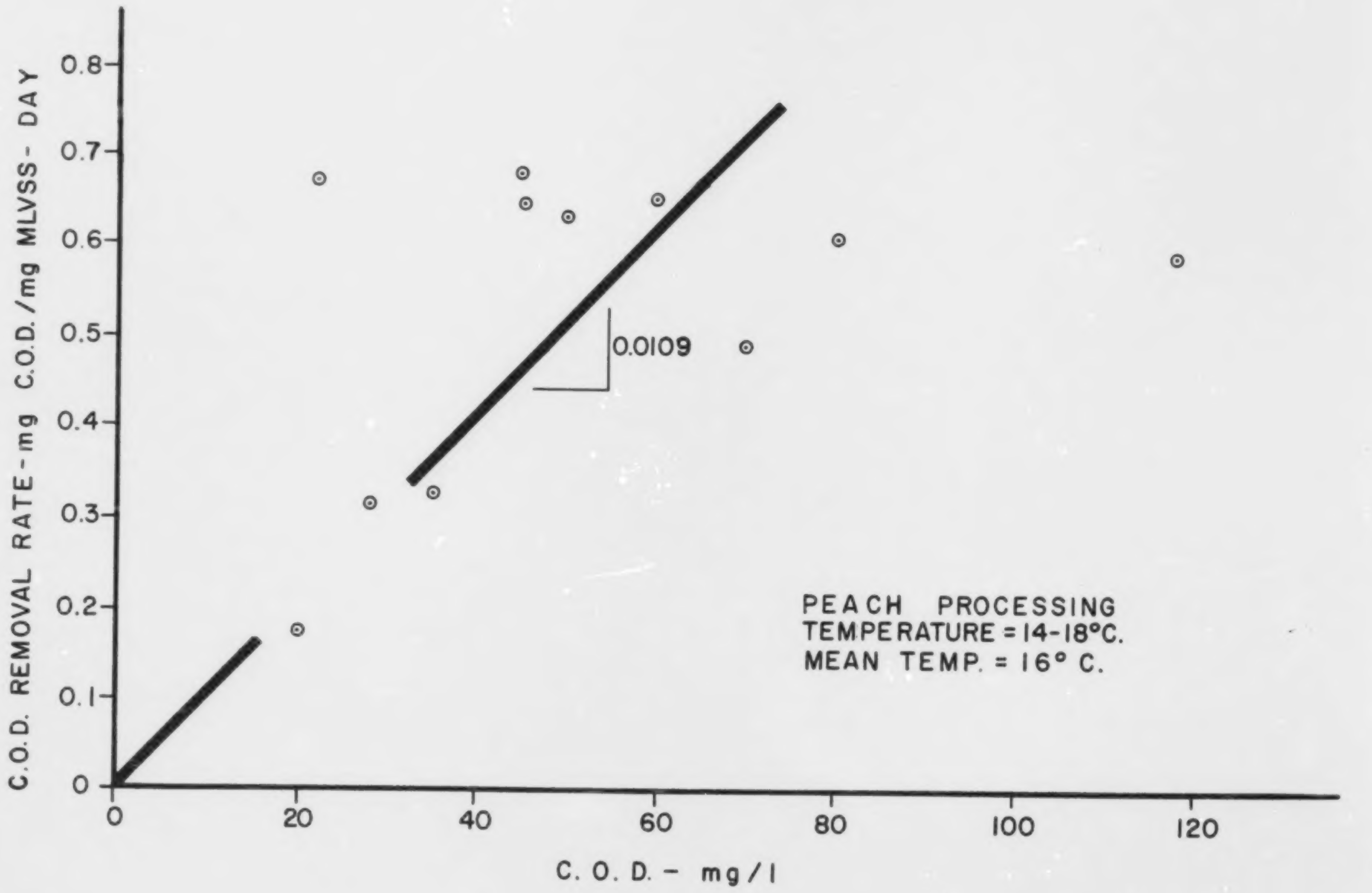

FIG. 24. — C.O.D. REMOVAL RATE VS CONCENTRATION

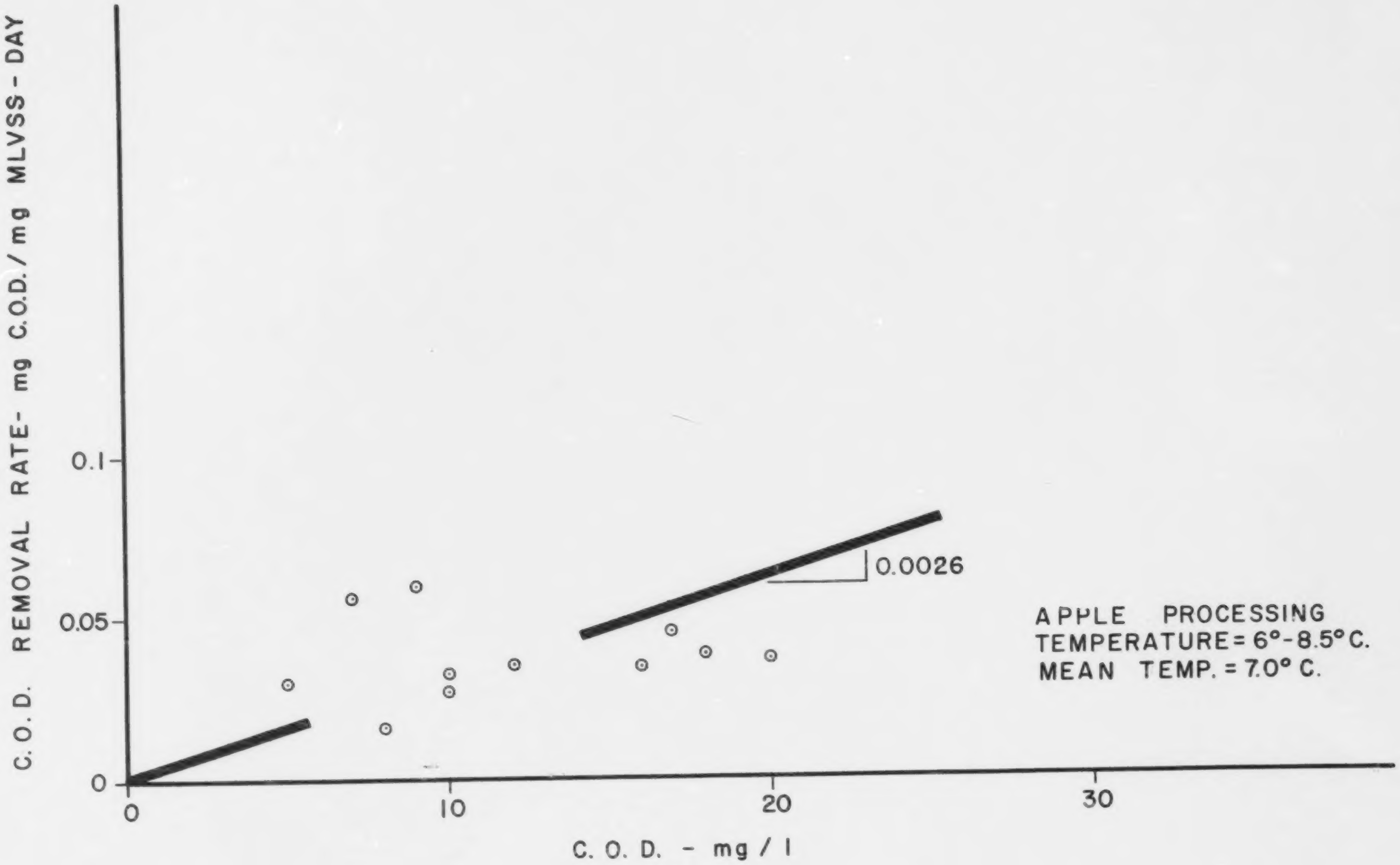

FIG. 25. — C.O.D. REMOVAL RATE VS CONCENTRATION

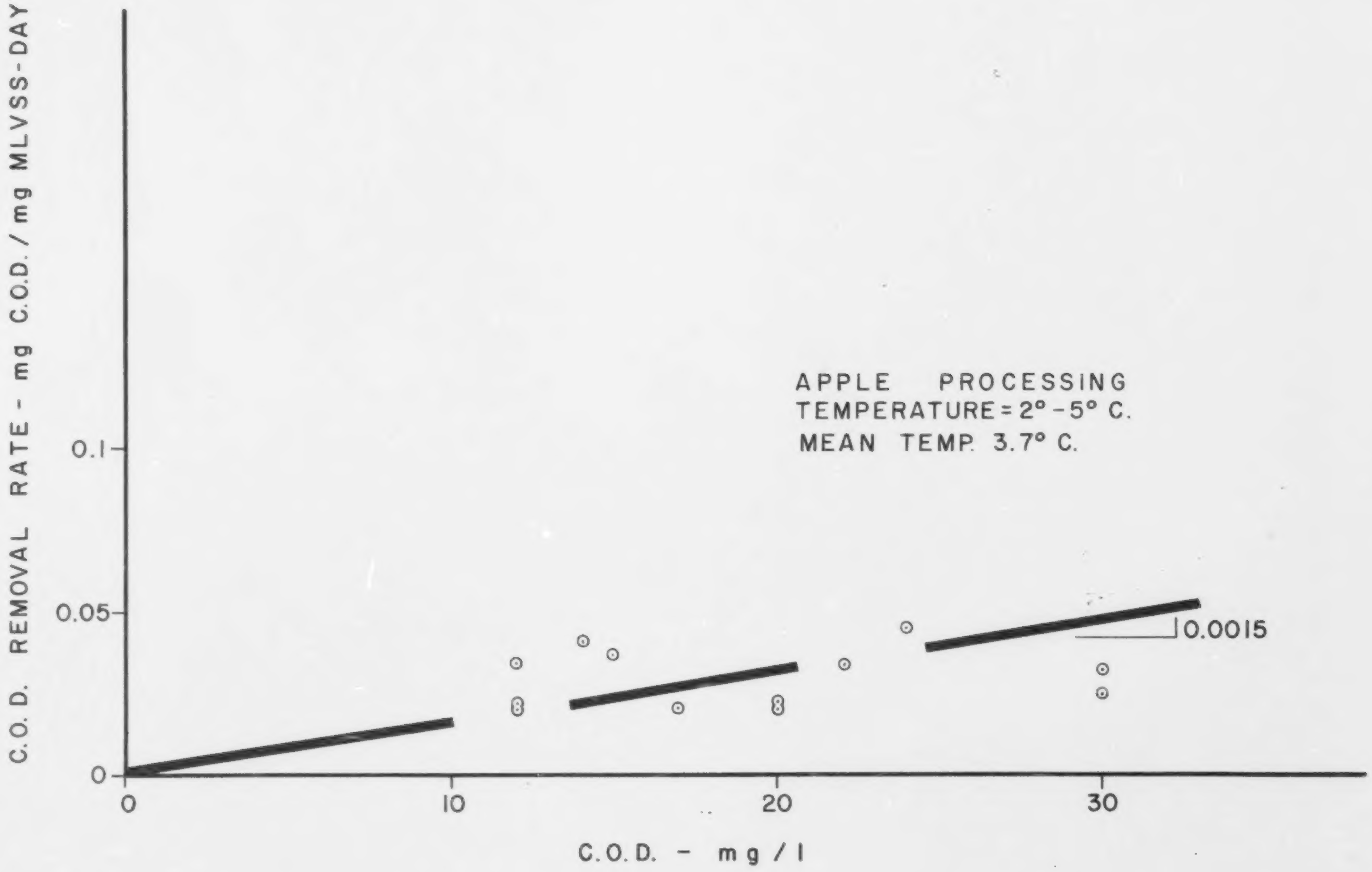

FIG. 26. — C.O.D. REMOVAL RATE VS CONCENTRATION

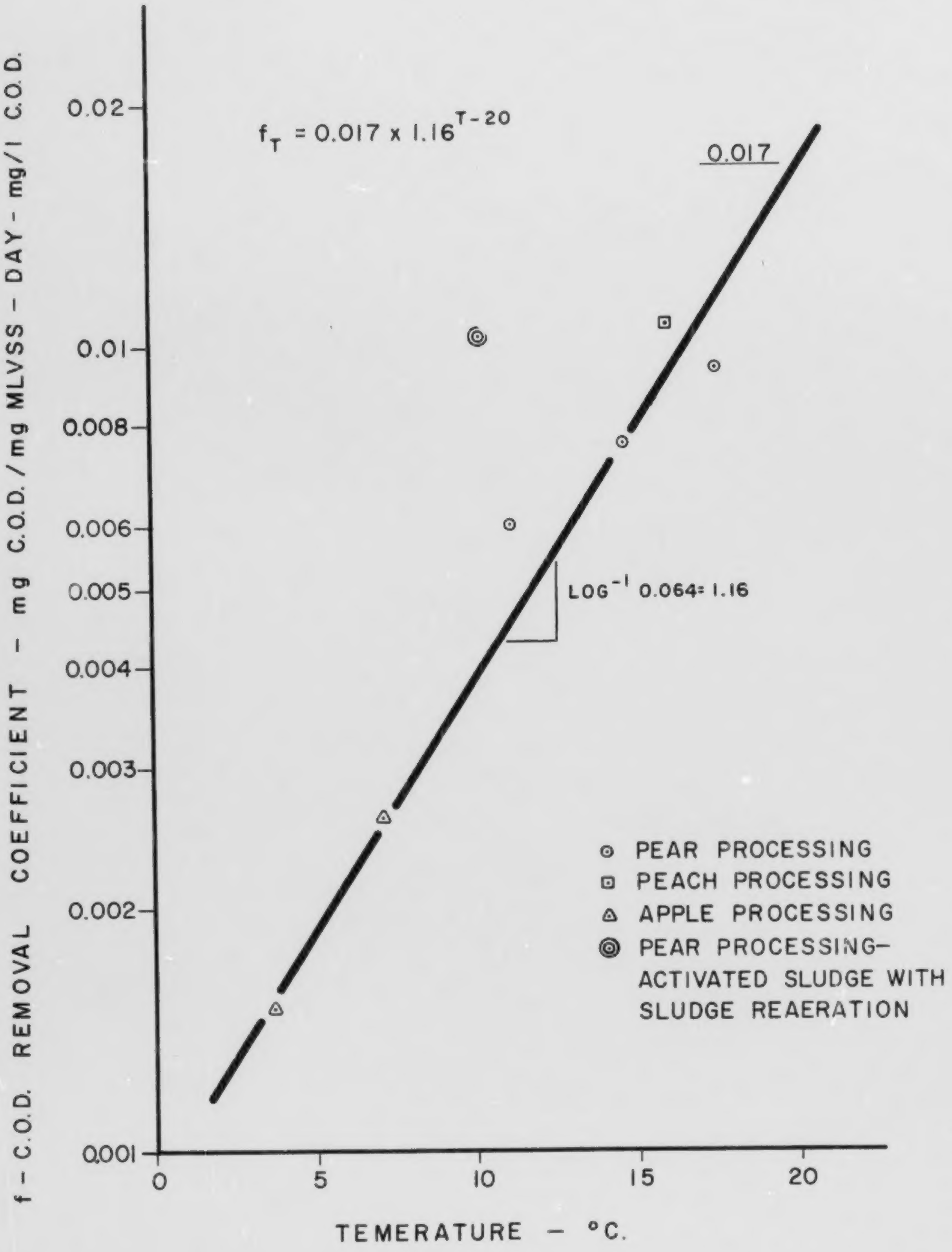

FIG. 27. — C.O.D. REMOVAL COEFFICIENT VS TEMPERATURE

f_T = COD Removal Coefficient at T° C

T = Temperature °C

If there can be assumed a consistant ratio of influent BOD to COD and a consistant ratio of effluent soluble (or substrate) BOD to COD, then the removal coefficient for BOD would follow a temperature dependance curve of the same slope as the COD removal coefficient. Therefore

$$f_{BOD_T} = f_{BOD_{20}} \times 1.16^{(T-20)}$$

where

f_{BOD_T} = BOD removal coefficient at temperature T° C

$f_{BOD_{20}}$ = BOD removal coefficient at 20° C

and

$$R_{BOD} = f_{BOD}s = f_{BOD_{20}} \; 1.16^{(T-20)} \; s$$

where

R_{BOD} = BOD removal rate = $\frac{\text{mg BOD removed}}{\text{mg MLVSS-day}}$

it follows that

$$f_{BOD_{20}} \; s = R_{BOD} \; 1.16^{(20-T)}$$

By taking what BOD data is available and adjusting it according to this equation and plotting (Figure 28), a value for $f_{BOD_{20}}$. can be obtained. This results in

$$f_{BOD_T} = 0.068 \times 1.16^{(T-20)}$$

The curve on Figure 28 was plotted through the median value not considering the points resulting from pear processing activated sludge with sludge reaeration.

BIOLOGICAL GROWTH

As it was pointed out earlier and according to the equations (3) and (5), the sludge growth is directly proportional to the BOD or COD removed and the net sludge growth is the sum of the sludge growth and the endogenous respiration which is a negative number. The constants in the sludge growth equation can be determined by plotting the net sludge growth in milligrams of volatile suspended solids produced per milligram mixed liquor volatile suspended solids/day versus the BOD or COD removal rate in milligrams of BOD or COD per milligram of MLVSS-day. During the project considerably more data was collected on COD removal rates due to the excessive length of time taken to run BOD tests than was BOD data. As it was pointed

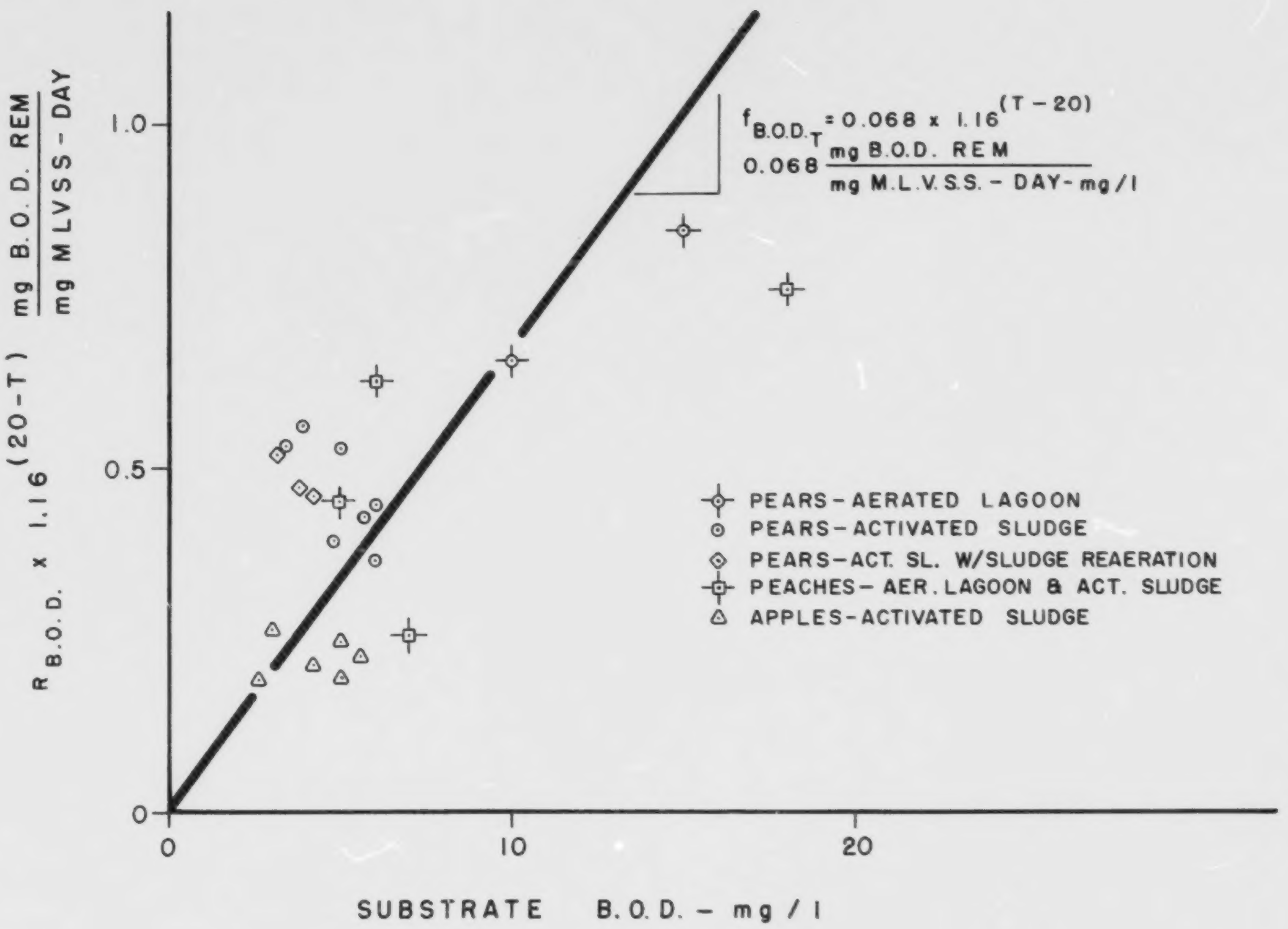

FIG. 28 — B. O. D. REMOVAL RATE VS CONCENTRATION AT 20° C.

out earlier, the biological growth, or sludge growth, was measured as volatile suspended solids during the project.

The net sludge growth was plotted versus the COD removal rate according to the product being processed. It was noted that a wide range existed in some of these plots so each of these was plotted once again according to temperature of the aeration basin during the operation. This separation according to temperature yielded plots which had a constant slope for a given product being processed, but which had different intercepts on the axis, thereby giving a different endogenous respiration rate constant. The slope of the curve is the sludge growth constant. Figures 29 through 34 contain the plots of net sludge growth versus COD removal rate and are divided according to product being processed and the temperature in the aeration basin. As can be seen, Figures 29, 30, and 31, which all resulted from pear processing, contain the same slope to the plot but different intercepts on the net sludge growth axis. Figure 32 was plotted utilizing the same slope since the product being processed was the same in order to determine the intercept for that method of processing and temperature. The COD removal rate for Figure 32 was computed using total VSS in the system. Figure 33 for peach processing obtained a slightly different slope and intercept than was experienced on the pear processing figures while Figure 34 obtained a slope for apple processing which was quite different from that for either pears or peaches. Although purple plums were run during the peach and pear processing season, their volume was so small in comparison to the peach or pear volume, the constants here are assumed to be for the major product processed at the time. On Figure 34 a further breakdown of data according to temperature did not separate the lines sufficiently to make it worthwhile.

In equation (5) the slope of the curve from these plots is $\underline{c}$, sludge growth constant and the intercept is $\underline{k}$, the endogenous respiration rate

$$G = c\,R - k \tag{5}$$

The endogenous respiration rates established from the net sludge growth versus COD removal rate plots were plotted versus temperature in degrees centigrade on Figure 35. The endogenous respiration rate when plotted on a semilogarithmic scale versus the temperature on arithmetic scale shows a straight line relationship according to temperature and once again follows a form of the Arrhenius equation [2]. This relationship, equation 11

$$k_T = 0.115 \times 1.14^{(T-20)} \tag{11}$$

k_T = Endogenous Respiration Rate at Temperature T-°C

gives endogenous respiration rate for the volatile suspended solids measurement of biological solids grown on the fruit processing waste

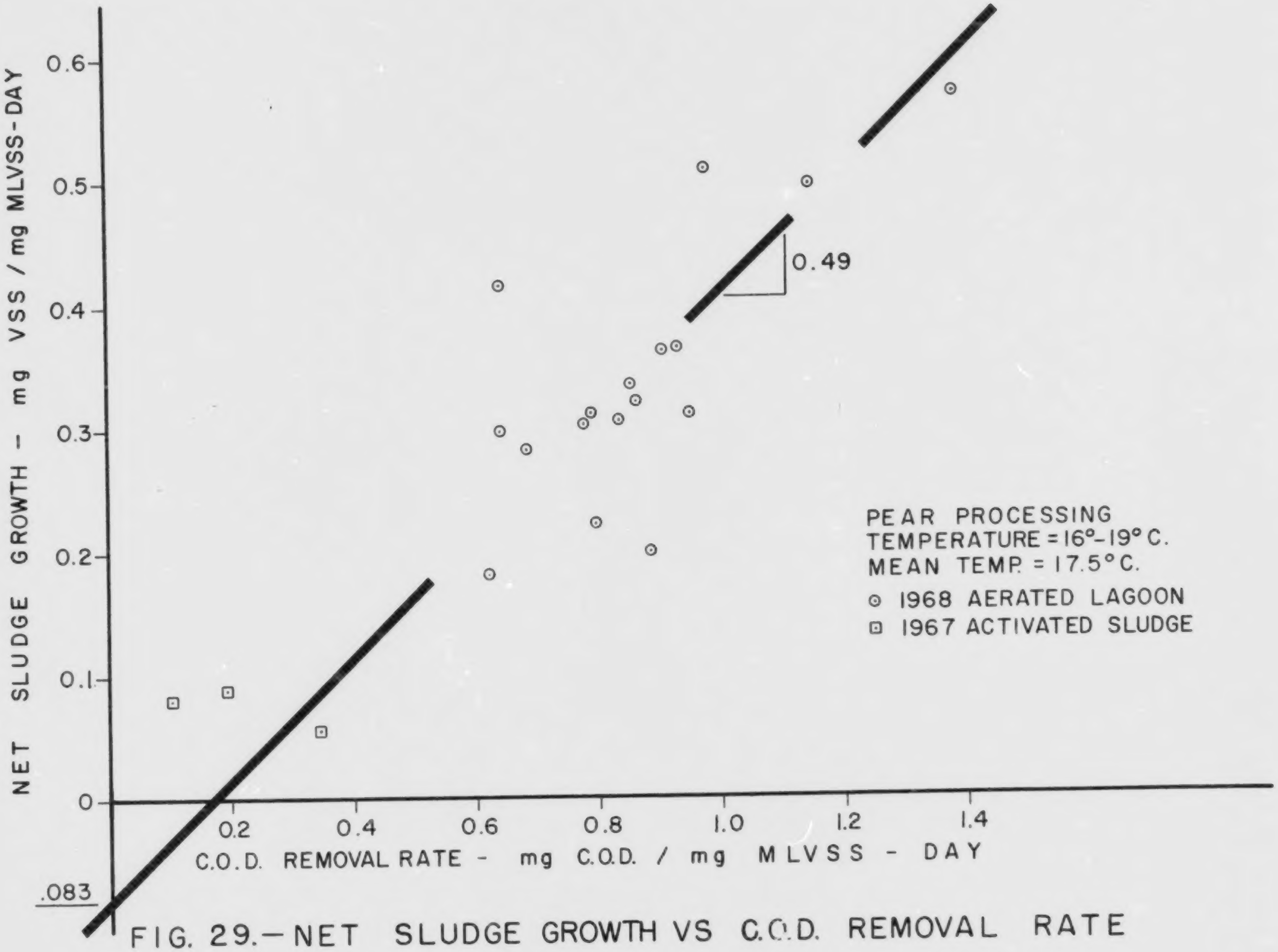

FIG. 29.—NET SLUDGE GROWTH VS C.O.D. REMOVAL RATE

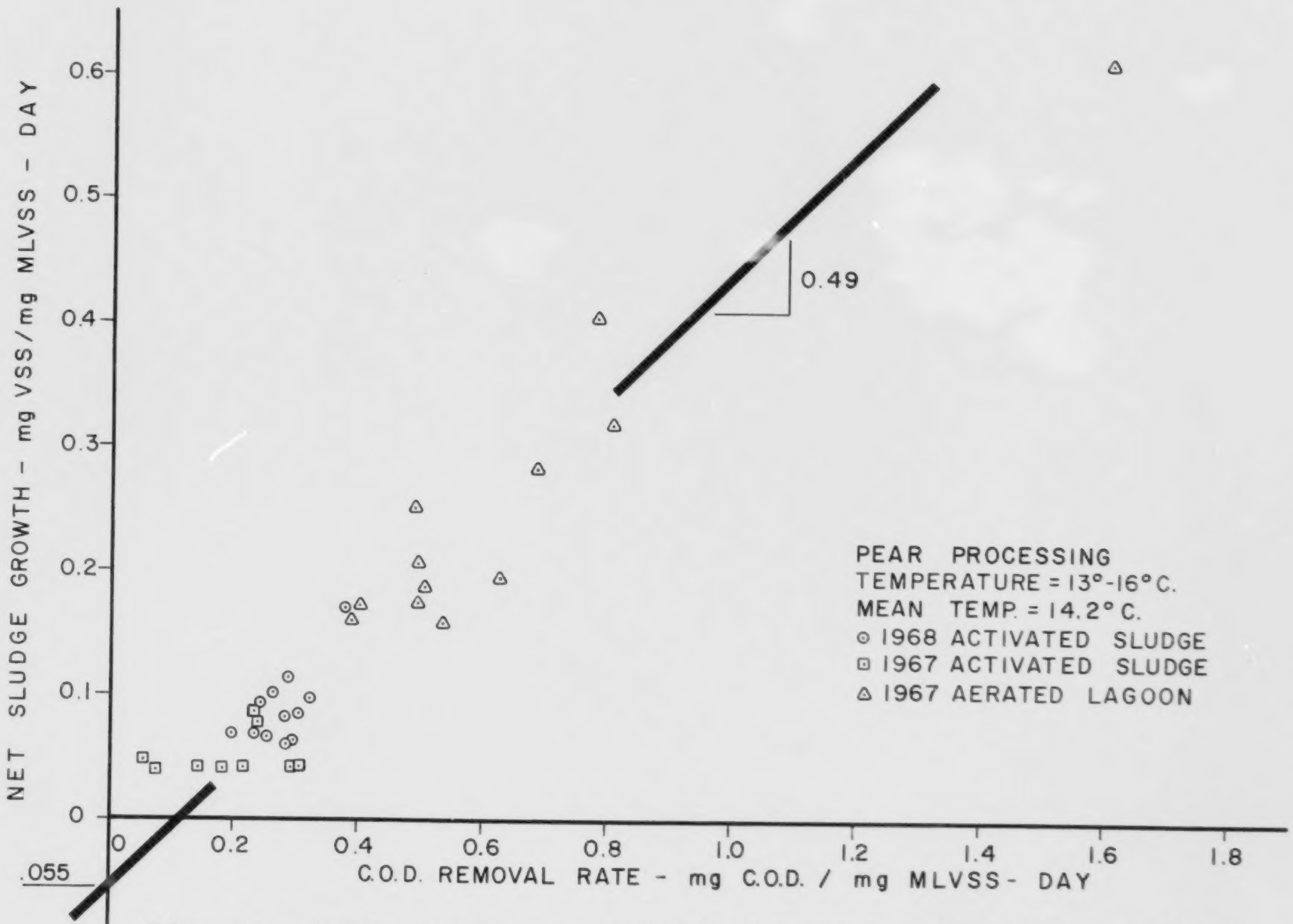

FIG. 30.—NET SLUDGE GROWTH VS C.O.D REMOVAL RATE

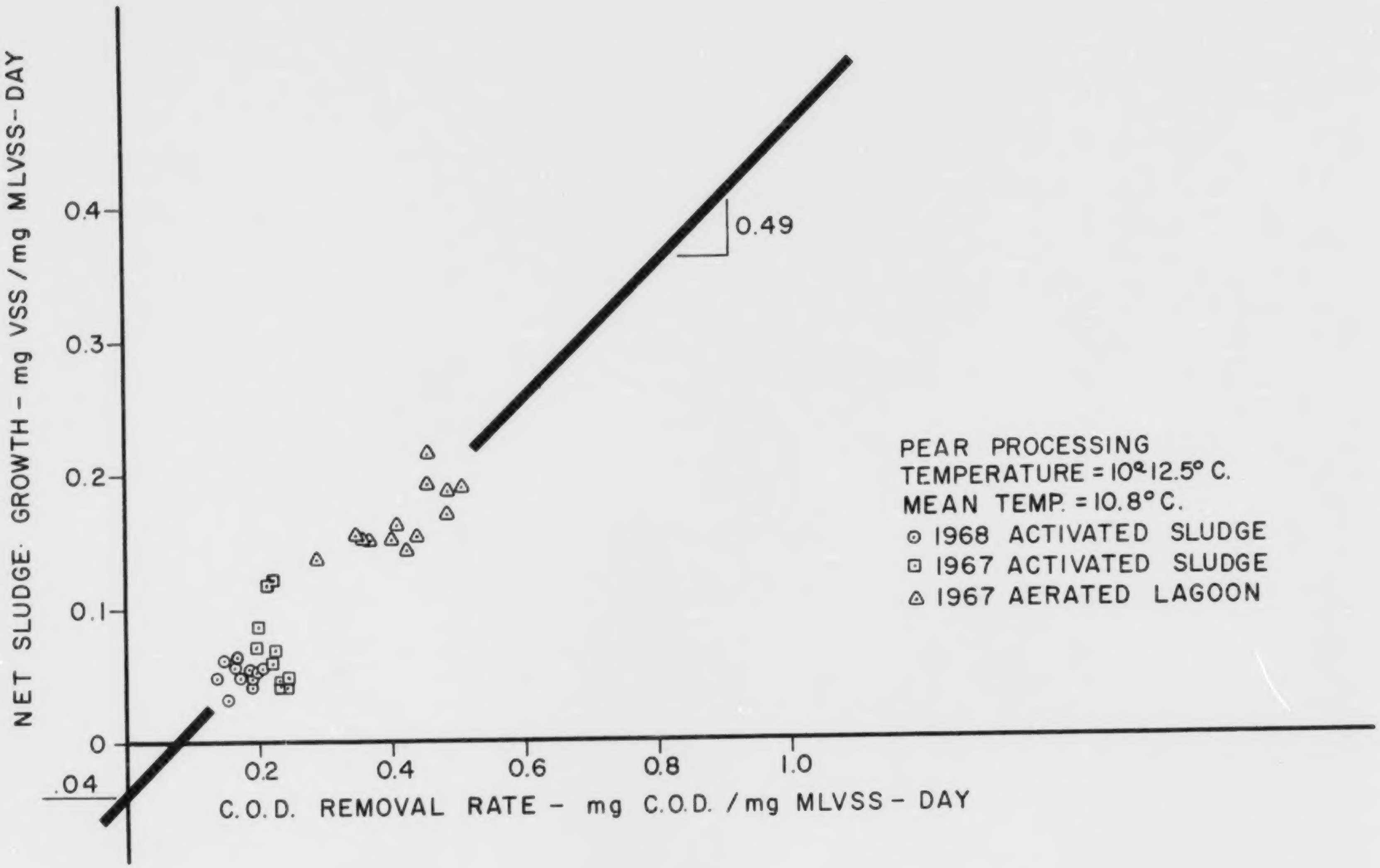

FIG. 31. — NET SLUDGE GROWTH VS C.O.D. REMOVAL RATE

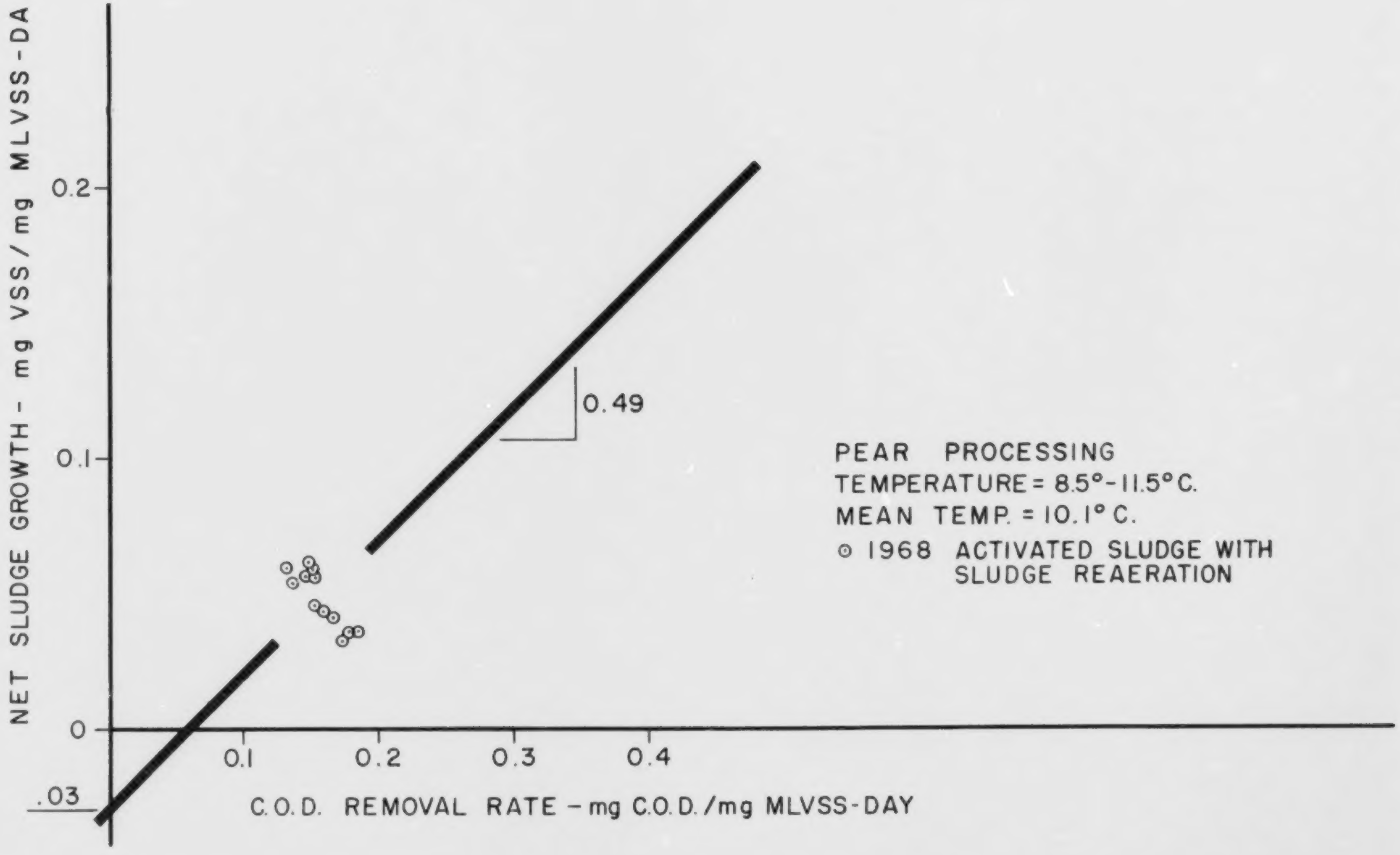

FIG. 32.—NET SLUDGE GROWTH VS C.O.D. REMOVAL RATE

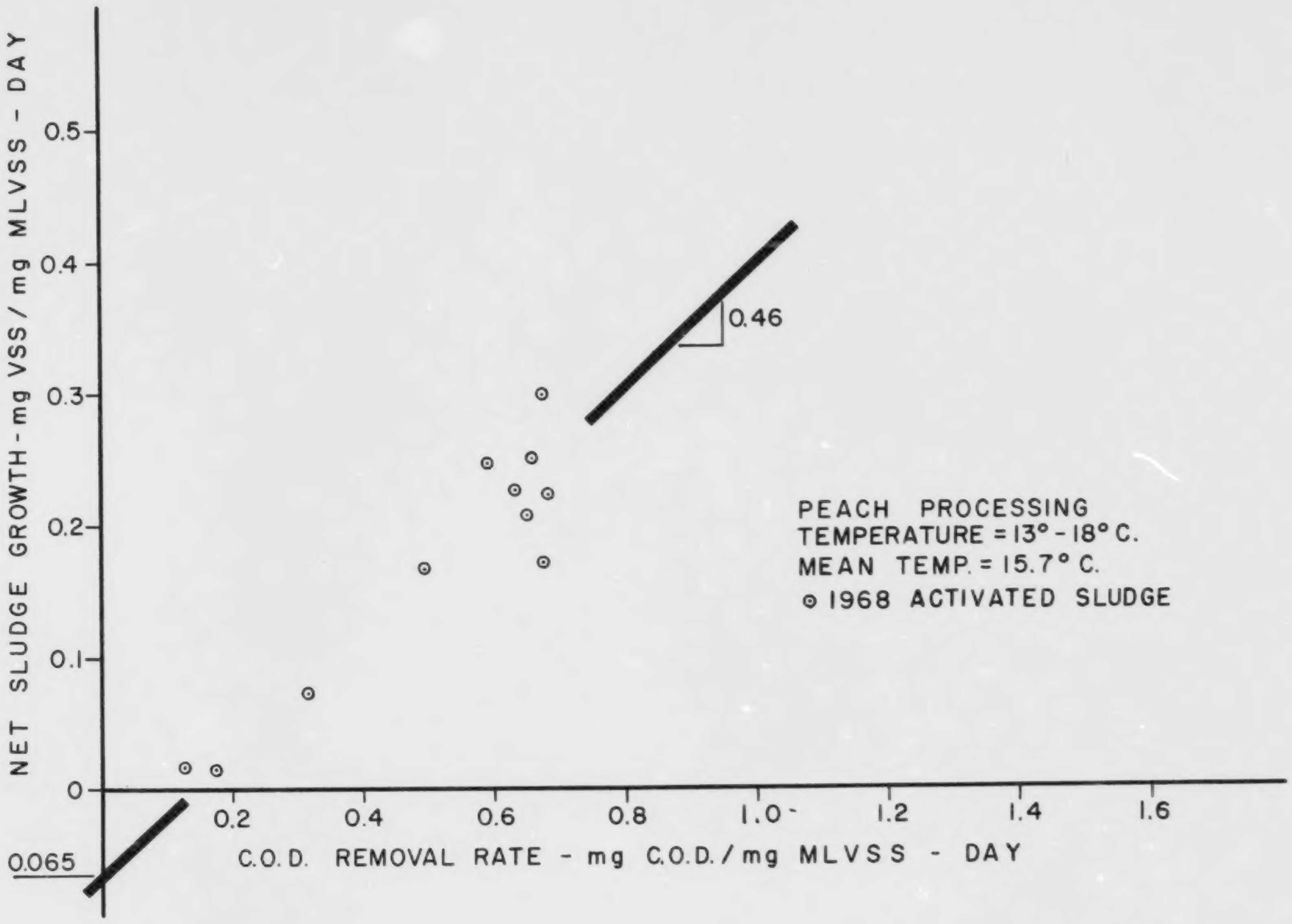

FIG. 33. — NET SLUDGE GROWTH VS C.O.D. REMOVAL RATE

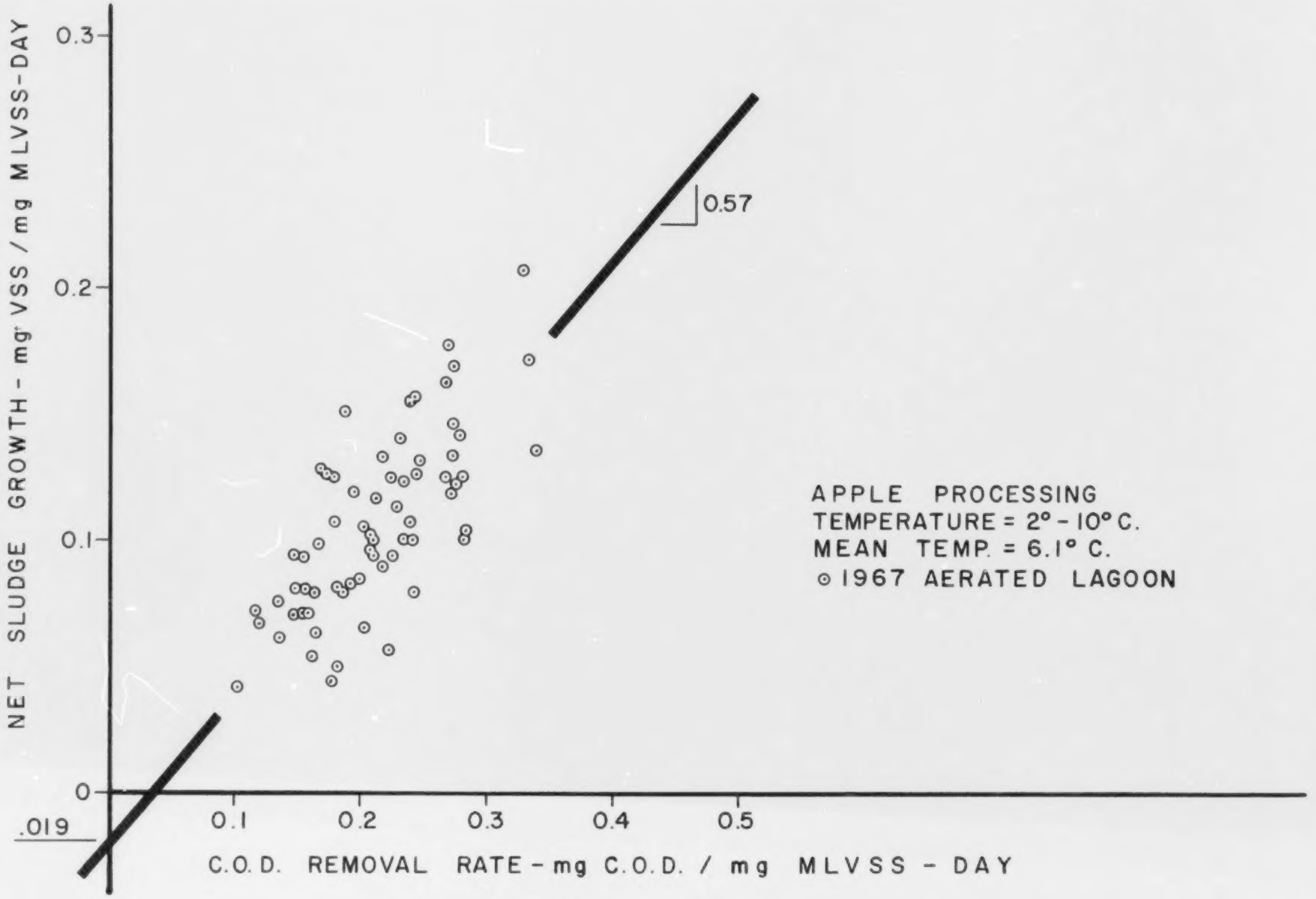

FIG. 34. — NET SLUDGE GROWTH VS C.O.D. REMOVAL RATE

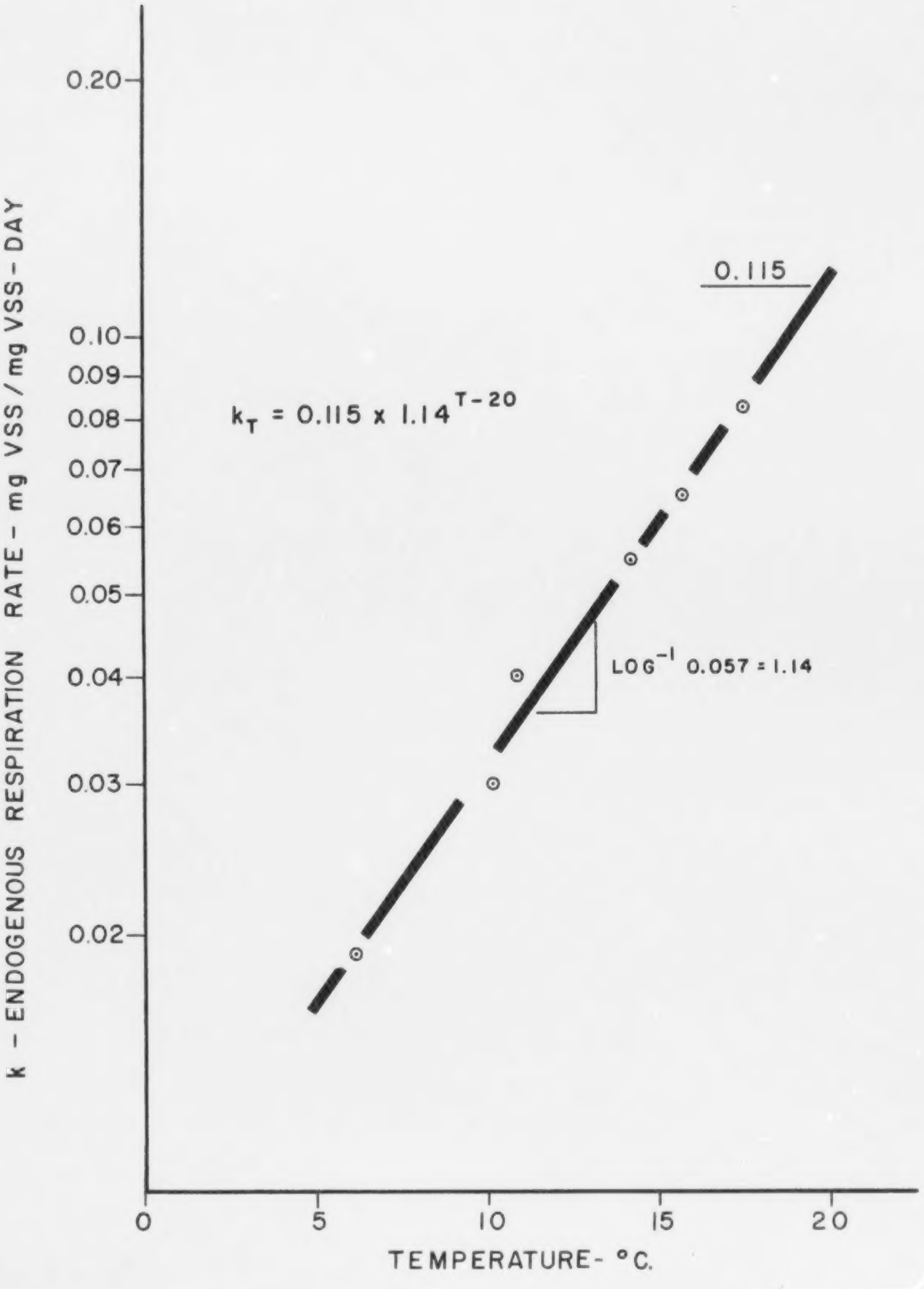

FIG. 35.– ENDOGENOUS RESPIRATION RATE VS TEMPERATURE

at the temperature at which the aeration basin is operated. The relationship shows that the endogenous respiration rate increases with higher temperature through the temperature range recorded during the study. It also shows that the endogenous respiration rate of the sludge was apparently independant of product processed.

The sludge growth constants which are given on the individual charts in milligrams VSS/mg COD removed can be converted to sludge growth constants in mgVSS/mg BOD removed by using the BOD over COD ratio for the particular product being processed. A summarization is as follows:

Product Being Processed	Sludge Growth Constant mgVSS/mgCOD Removed	Sludge Growth Constant mgVSS/mgBOD Removed
Pears	0.49	0.66
Peaches	0.46	0.69
Apples	0.57	0.76

The endogenous respiration rate (k) would not change between BOD and COD consideration since it acts on the volatile suspended solids.

OXYGEN REQUIREMENTS

The oxygen requirements for an aerated system depend upon the amount of organic matter removed from the waste stream and on the amount of volatile suspended solids in the aeration system as was described by equations (6) and (7).

$$O_2 = a \cdot \text{BOD or COD removed} + b \cdot k \cdot \text{MLVSS} \qquad (6)$$

$$O_2/\text{MLVSS} = a \cdot R + b \cdot k \qquad (7)$$

The two constants a and b can be determined by plotting the oxygen uptake rate by the aerobic system versus the BOD or COD removal rate. This plot yields a straight line curve through the data with the slope of the line being a and the intercept on the oxygen uptake rate axis being $b \cdot k$. b would be determined by dividing $b \cdot k$ by the endogenous respiration rate (k) at the particular temperature at which the set of oxygen uptake rate data was gathered.

As is explained in Appendix D, the oxygen uptake rate studies made with dissolved oxygen probe and meter were not necessarily at the temperature at which the aeration system was being operated at the time since the samples following their collection warmed up prior to running the oxygen utilization curve and also warmed up during the running of the test. Temperatures were taken during the tests, however, and the temperature gained during the test calibrated so that the temperature of reaction in the vessel used for the oxygen uptake rate test was known. The majority of the tests run were at approximately 16° C., but some tests necessarily had to be run lower or above that and some results from 12° C. and 20° C. were collected. On some of the tests which lasted a long period of time, tangential plots of the curve at more than one temperature were possible. These plots of individual tests are shown in Appendix D. The oxygen uptake rate versus COD removal rate for the days on which the uptake rate was run are plotted on Figures 36, 37, and 38. For the plotting of the curve through the data points, it was assumed that the slope of the curve would be constant on each of the plots and that only the intercept would change with temperature. As it appears from the data points plotted, this appears to be a valid assumption. From these figures, it can be seen that

$a = 0.34 mgO_2$ required/mgCOD removed

By utilizing the approximate average BOD over COD ratio of the raw wastes of 0.74, it can be seen that a also has the value

$a = 0.46 mgO_2$ required/mgBOD removed

By taking the intercept of the plot from these three figures and k as determined from Figure 34 for the applicable temperature, average

$b = 1.2 mgO_2$ required/mgVSS

Using the constants already established and knowing the mixed liquor volatile solids in the aeration system and the aeration basin temperature, the oxygen transfer efficiency of the surface aerators used in this treatment facility can be computed. Table VII shows computations for aeration efficiency for different days through the two processing seasons as calculated using these constants and formulas. These days were not selected at random but were selected to show what the probable maximum aerator oxygen transfer would be during the operation season. It is shown from this table that the aerators can probably be relied upon to produce an aeration efficiency of 2# of oxygen transfer/HP hour expended for design. It would also be apparent, though, that the larger units would have as good an efficiency as smaller units if not, perhaps, slightly better. From the results available, not very much in excess of 2# oxygen transfer/HP hour expended could be relied upon. This means that the combined alpha and beta correction factors for the aerators would be 0.57 for an aerator rated at 3.5 pounds of oxygen transfer per horsepower hour of standard conditions.

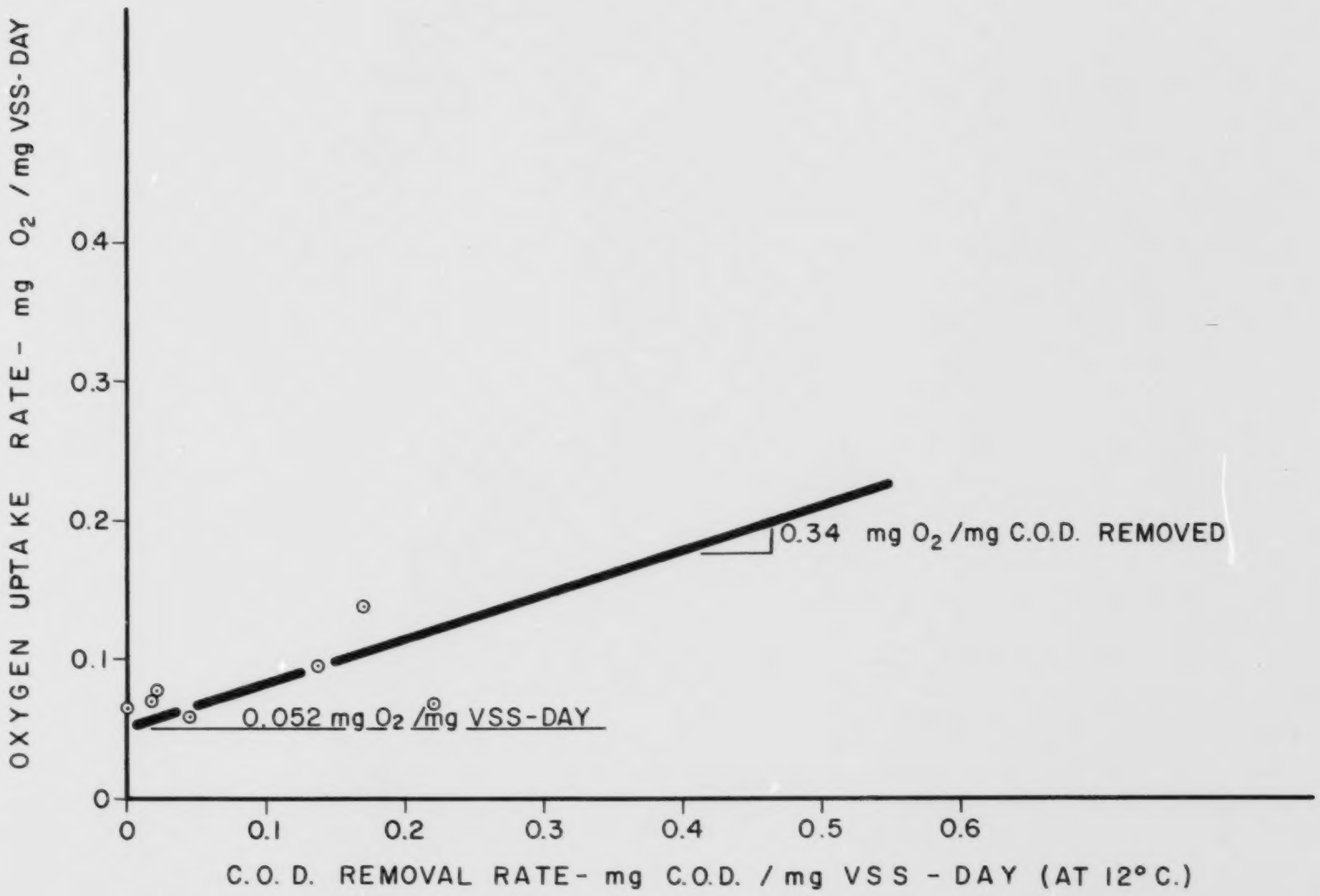

FIG. 36.— OXYGEN UPTAKE RATE VS C.O.D. REMOVAL RATE

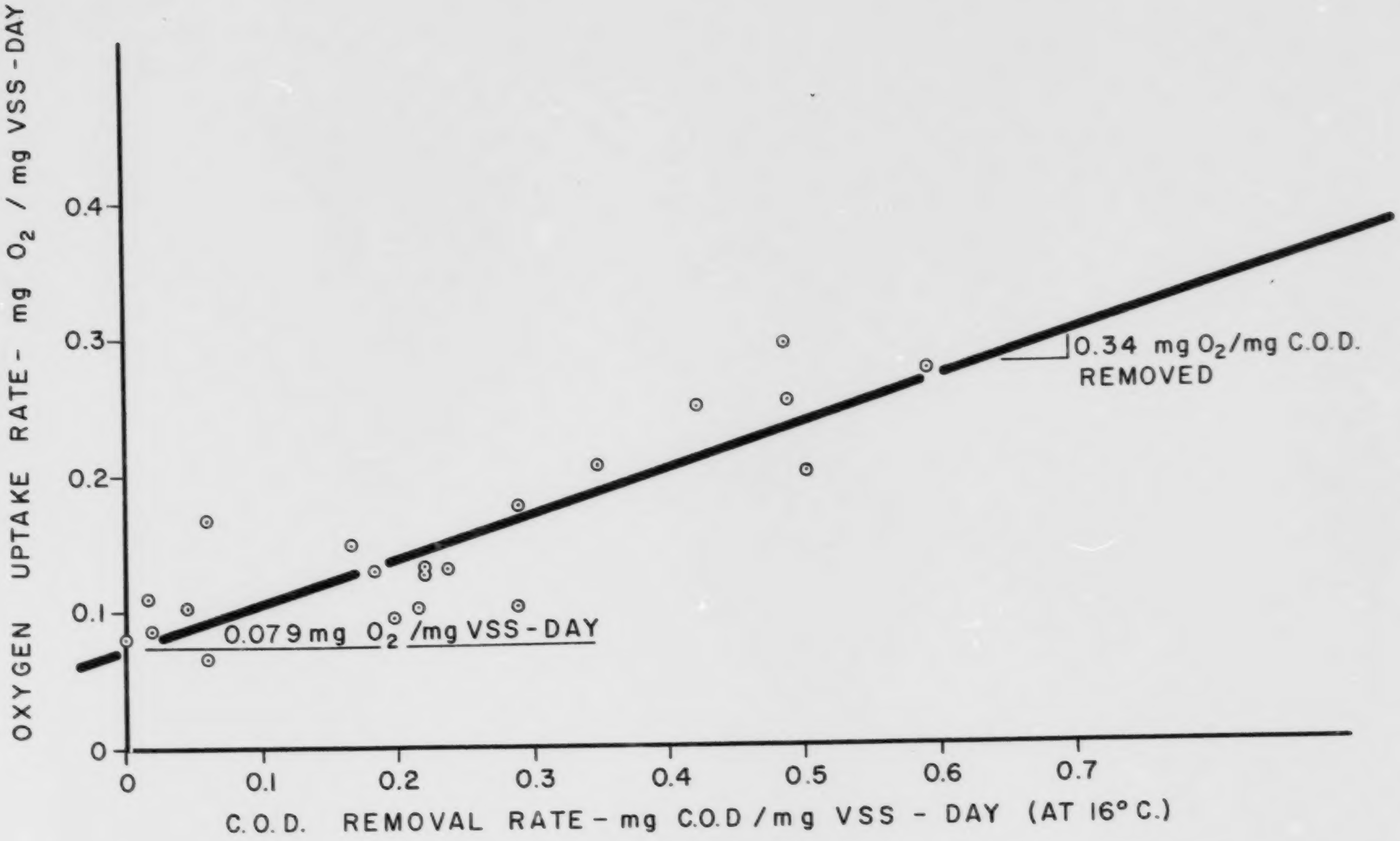

FIG. 37. — OXYGEN UPTAKE RATE VS C.O.D. REMOVAL RATE

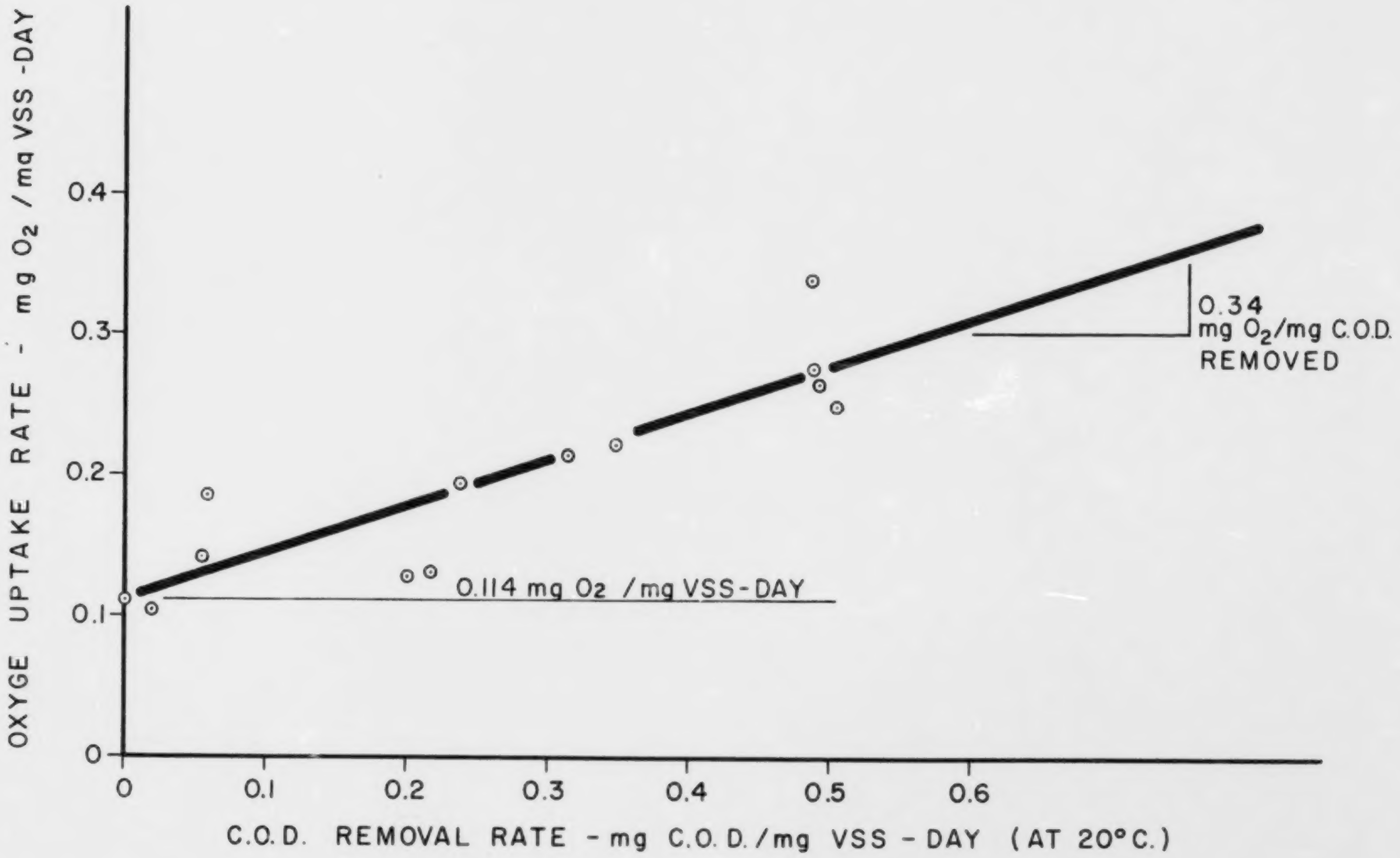

FIG. 38. — OXYGEN UPTAKE RATE VS C.O.D. REMOVAL RATE

TABLE VII

AERATOR OXYGEN TRANSFER EFFICIENCY

Date	Treatment System	Aeration DO mg/l	Basin Temp °C	$\#O_2$ Transferred (Calculated)	HP of Aerators In Use	$\#O_2$ per HP Hour
10/14/67	Activated Sludge	1.4	14.5	2,080	60	1.44
10/14/67	Aerated Lagoon	1.3	14.0	10,150	240	1.76
10/18/67	Activated Sludge	0.4	12.1	2,020	60	1.40
10/18/67	Aerated Lagoon	0.4	12.0	10,740	240	1.87
9/28/68	Activated Sludge	1.9	16.5	17,870	390	1.91
10/5/68	Activated Sludge	1.8	14.0	18,460	390	1.97
10/16/68	Activated Sludge	2.0	12.0	19,010	390	2.04
10/24/68	A.S. w/ Sludge Reaeration	2.9	12.8	19,700	450	1.82
10/26/68	A.S. w/ Sludge Reaeration	2.4	12.5	20,480	450	1.90

BOD AND COD CONTENT OF BIOLOGICAL SLUDGE

The BOD and COD equivalent of the biological sludge in an aerated system is important in the design and operation of the system since a certain amount of the biological solids are going to escape into the effluent. The amount of biological solids which escape depends on the design and operation of the facility and the efficiency of the individual treatment units, including the aeration system and the clarification system. As it was noted during both seasons of operation, the effluent quality for both BOD and COD depended very greatly upon the amount of biological sludge, measured as volatile suspended solids, escaping in the effluent.

Figure 39 shows the mgCOD/mgVSS versus the COD removal rate and the mgBOD/mgVSS versus the BOD removal rate for the processing seasons studied. As it can be seen from Figure 39, the ratio of COD to VSS does not change regardless of the removal rate of substrate by the biological solids in the system. However, the BOD of biological solids changes with the BOD removal rate and increases as the removal rate becomes greater. These relationships are as follows:

$$\text{mgCOD/mgVSS} = 1.39$$

$$\text{mgBOD/mgVSS} = 0.3 + 0.28 \times \text{BOD removal rate}$$

The reason for the BOD over VSS ratio being a function probably lies in the fact that the solids accumulate unoxidized material for which they utilize oxygen to synthesize new cells and that more of this material accumulates when the organisms are working at a higher rate and removing a higher amount of substrate per organism weight. The chemical oxygen demand, however, remains constant regardless of the loading rate since this unoxidized material converts to cellular material still having the same chemical oxygen demand but which has a lower biochemical oxygen demand.

In determining the efficiency of a system in the design these ratios of COD and BOD to VSS must be taken into consideration in order to assure the compliance with standards which may be imposed upon a treatment system. The efficiency of the removal of a system will depend largely upon the efficiency of the removal of these volatile suspended solids or biological sludge from the effluent assuming that aeration and nutrients and other factors are sufficient for the proper treatment of the waste.

It can now be seen why the BOD removal efficiency improved while the COD removal efficiency deteriorated in the aerated lagoon while going from pear processing to apple processing waste. It is recalled that an increase in detention time in the lagoon resulted, but also that the treatment of apple processing waste occurred during much colder weather. The lower temperatures slowed the rate of endogenous respiration (Figure 37), thereby allowing a higher MLVSS to be carried in relation to the inflowing waste. The longer detention time allowed a lower loading on these solids, thereby reducing their BOD exertion. Since the BOD content of the solids was reduced more than enough to offset the concentration increase due to temperature, a greater BOD overall removal efficiency was realized while COD content of VSS remained the same, so COD overall removal efficiency deteriorated.

NUTRIENT REQUIREMENTS

It was attempted to monitor the performance of the system in relation to the nitrogen and phosphorus feeding rates and/or content of the biological solids during this study. The 1967-1968 season data, however, did not show very much correlation in any way, principally because of the data collected. The data collected during that season on nutrient content of the biological sludge was principally preserved

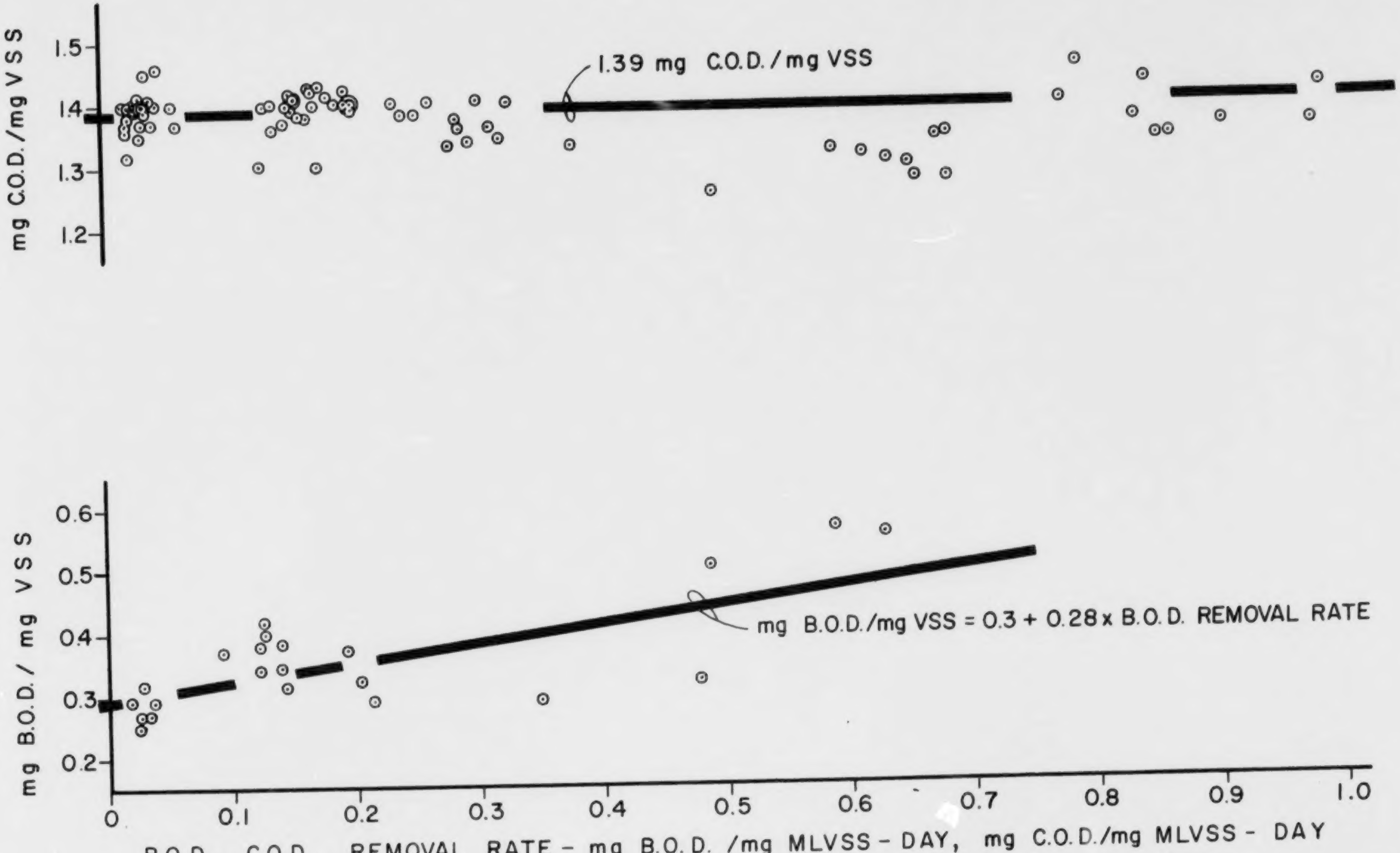

FIG. 39. — B.O.D., C.O.D. EQUIVALENT OF VSS

samples, mostly canned. As it was stated elsewhere, these canned samples gave unreliable data as to the form of the nitrogen and phosphorus in the sample and it could not be determined which portion was organic and which portion was not organic in the biological sludge samples. The 1968 operating season data was much more reliable from a sampling and analysis standpoint, but it was still very difficult to determine any particular trends in treatment characteristics related to the feed rate or content of these nutrient elements.

The results of the analysis on the biological sludge during the 1968 processing season are presented on Figure 40 and plotted against the COD removal rate at the time of the sampling. Preliminary inspection of the data points as plotted would indicate that there would be some trend where the nitrogen and phosphorus content in the volatile solids measurement of the biological sludge vary as the COD removal rate. Consideration of the data, however, precludes us from making any final conclusions as to this possibility, since all of the data points progressed during the season timewise from right to left on this chart. The points for high COD removal rates were collected during the initial part of the season and for the lower COD removal rates at the latter part of the season and it is difficult to state positively that there was sufficient nutrient in the inflowing waste to not deprive the organisms partially during the initial part of the season. Actually, there was no measurable soluble nitrogen in the effluent when the lowest four N/VSS points were collected and no measurable ortho phosphate when the two lowest P/VSS points were collected. Further study would appear to be desirable on this particular aspect of biological waste treatment and it is probable that any trends found here would not be characteristic of fruit processing waste biological treatment but would be characteristic of aerobic biological treatment of other wastes as well. It can only be concluded that with sufficient nutrients available as confirmed by residual nutrients being present in the clarified waste stream from the biological treatment system, that the approximate average nutrient contents of the biological sludge for this study were as follows:

Organic P/mgVSS = 0.016mg
Organic N/mgVSS = 0.087mg

These figures were not seen to go higher due to excess availability of nutrients as more soluble nutrients (both N and P) were available for the points at COD removal rates below 0.1. Since there is a constant amount of biological sludge growth per weight of BOD or COD removed, it is evident that there must be a certain amount of nitrogen and phosphorus in relationship to this BOD or COD in order to sustain proper growth of the organisms forming. However, at the same time, there is nitrogen and phosphorus being released from the breakdown of biological sludge by endogenous respiration. It has been stated [9] that there is not a complete release of these nutrients by endogenous respiration since there is a certain amount of the biological sludge which is relatively inert and does not break down by endogenous respiration. A figure of 20% was suggested for this amount [9]. Using the proportions of nitrogen and phosphorus in the volatile suspended solids formed, COD and BOD removal and the

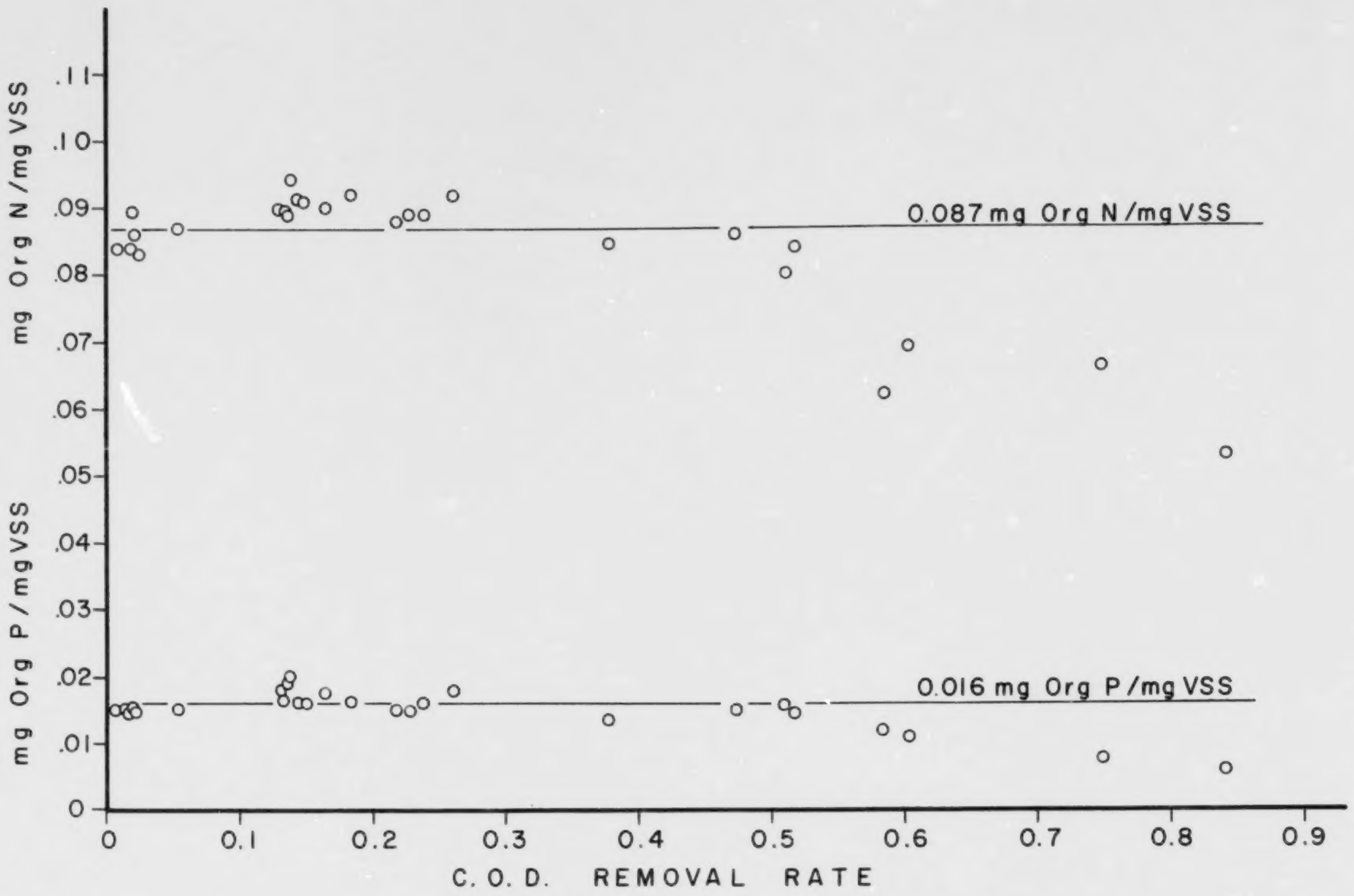

FIG. 40.—NITROGEN AND PHOSPHORUS CONTENT OF BIOLOGICAL SLUDGE

assumption that 20% of the nitrogen and phosphorus is non-returnable to the system by endogenous respiration, the following formulas can be derived for the nitrogen and phosphorus required for BOD and COD removal.

$$N/COD \text{ Removed} = 0.087c_{COD} - 0.80 \times 0.087k/COD \text{ Removal Rate}$$

$$N/BOD \text{ Removed} = 0.087c_{BOD} - 0.80 \times 0.087k/BOD \text{ Removal Rate}$$

$$P/COD \text{ Removed} = 0.016c_{COD} - 0.80 \times 0.016k/COD \text{ Removal Rate}$$

$$P/BOD \text{ Removed} = 0.016c_{BOD} - 0.80 \times 0.016k/BOD \text{ Removal Rate}$$

where

$$k = 0.115 \times 1.14^{(T-20)}, \ T = \text{Aeration Basin Temperature}$$

Using these formulas, the curves on Figure 41 were plotted using the sludge growth rate for pears and the endogenous respiration rate at the various temperatures for which the curves were plotted. As can be seen from the curves, there is a minimum amount of nitrogen and phosphorus required even though the net sludge growth rate would be theoretically zero at the point which these curves intercept the minimum N/COD and minimum P/COD lines. This is because at a steady state of operation, a zero net sludge growth rate cannot be practically attained and equations (3) and (5) would not be valid. Figure 41 also shows that the point at which zero net sludge growth is theoretically reached depends upon the temperature, due to the dependence upon temperature of the endogenous respiration rate.

It can be seen from Figure 41 that at removal rates in excess of approximately 0.5 there is little saving in nutrient requirements below what is required for conversion of the substrate directly into biological solids with no endogenous respiration taken into account. At below approximately 0.5mgCOD/mgMLVSS-day removal, there is considerable saving, depending upon temperature, of nutrients according to these theoretically derived curves.

Effects of Nutrient Deficiency

It is difficult to correlate the action of the treatment system during these processing seasons to nutrient content or nutrient addition, but it is possible that some of the observed portions of the processing season when poor sludge settling and separation characteristics occurred were due to deficiencies. The data collected was not sufficiently frequent or accurate during the 1967-1968 processing season to determine if this was the case. During the 1968 processing season, it is possible that there was a slight deficiency in the beginning of the season since during the early season the residual ammonia nitrogen and phosphate in the clarified waste was at or near zero. However, later in the season when the slowest settling conditions occurred in the tests, the ammonia and/or nitrate nitrogen

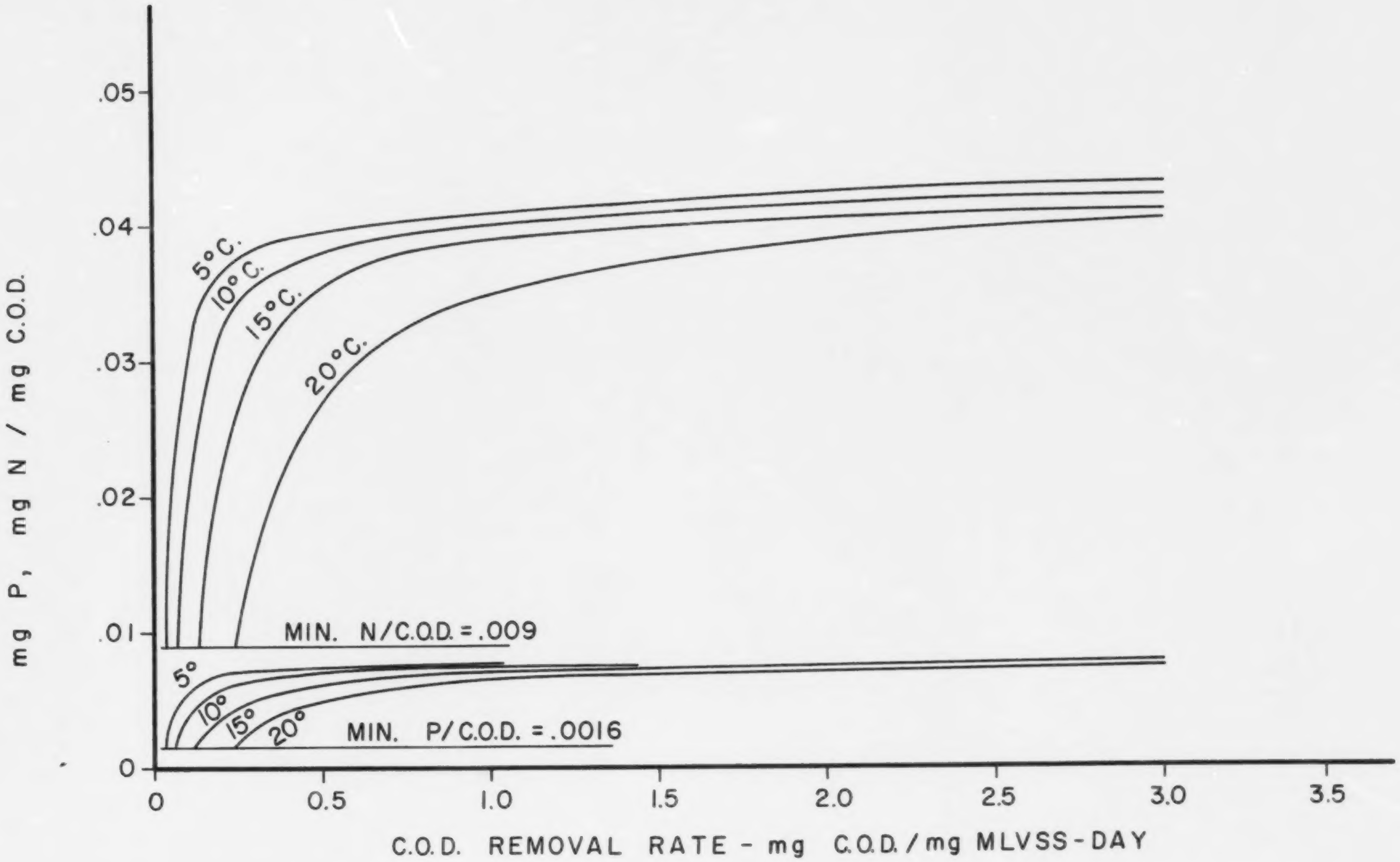

FIG. 41. — NITROGEN & PHOSPHORUS REQUIREMENTS FOR TREATMENT

contents in the residual waste following clarification were well above 1 mg/l and the phosphate content was also well above 1 mg/l which would indicate that the organisms had sufficient nutrient available to take up all that they required.

During May of 1969, the cannery had a short run on apples which had come out of storage and during this run the small aeration basin was operated as an aerated lagoon but with no nutrient addition to try to evaluate the effect on treatment characteristics when nutrient was totally deficient. After operating the system for about two weeks without nutrients, a two day sampling program was undertaken. The nutrients in the raw waste had a ratio of nitrogen and phosphorus to COD of only N/COD = 0.14/100 and P/COD = 0.06/100 and no measurable amount of either N or P remained in the effluent. The organic sludge, or what was measured as organic sludge developed in the system measured as VSS, contained only 0.04mg N/mg VSS and 0.0052mg P/mg VSS.

The BOD and COD removal rate was effected severely and differed greatly from what would have been expected from the data accumulated earlier with respect to the residual soluble BOD and COD available for uptake. The COD removal rate experienced was approximately 0.76mg COD removed/mgMLVSS-day. From this removal rate, a soluble COD concentration at the temperature of the lagoon (19° C.) computed from the curve presented earlier would have been 52mg/l. In the actual effluent the soluble COD over the two days of operation averaged 410 mg/l. The BOD expected from the removal rates experienced would have been only 14 mg/l but the actual BOD in the effluent following filtration was 220 mg/l. The net volatile suspended solids growth for the two days was 0.32 mgVSS/mgMLVSS. The calculated growth from the amount of COD removed was 0.33mgVSS/mgMLVSS for a very good correlation. The solids accumulated in the basin were very dispersed and did not tend to flocculate at all. No settlement of the solids occurred even following setting overnight.

It can be concluded from the experiment that a serious lack of nutrients effects flocculating and settling characteristics of the suspended solids adversely and also adversely effects the COD or BOD removal rate and makes the constants developed for that expression invalid. Further study could be carried out as to the extent of these effects and at what points nutrient deficiency effects actually begin to be demonstrated and the rate of progression of these effects with additional amounts of deficiency. Until further data is accumulated along these lines, it must be assumed that deficiency in nutrients below the approximate lines developed for Figure 41 would adversely effect the treatment efficiency and settling efficiency of an aerobic system.

BIOLOGICAL SOLIDS REMOVAL

The data gathered during study of fruit processing waste treatment by aeration has indicated the biological solids grown on the fruit processing waste do not settle as rapidly as those from domestic waste treatment systems. However, during the latter part of 1968, the biological solids settled out quite well to leave a very clear effluent with a very low suspended solids in the effluent. A relatively high sludge recirculation ratio of approximately 1:1 when taken as to the influent waste flow or greater, was maintained and this recirculation ratio seemed to quite adequately remove all of the solids from the clarifier and a very low proportion passed over the clarifier weirs into the effluent. It appears that the settleability and separation characteristics of the biological solids improve with a lower BOD or COD removal rate in the system. It also may be postulated that the settleability and separation characteristics of the biological solids deteriorates with inadequate nutrient feed to the system.

The Sludge Volume Index (SVI) is a measure of sludge settleability often used by sewage treatment plant operators in domestic sewage treatment plants as a measure of the settleability and compaction characteristics of activated sludge. The SVI is the settleable solids in milliliters per liter times 1,000 divided by the suspended solids in milligrams per liter and its units are milliliters per gram as shown in equation (12)

$$\text{SVI} = \frac{\text{Settleable Solids}}{\text{Suspended Solids}} \times 1000 \text{ ml/g} \qquad (12)$$

The sludge volume index is normally determined on the settleable solids after settling for one-half hour in a 1000 milliliter graduated cylinder and divided by the suspended solids of the sample. It can be used to determine the approximate concentration of returned sludge which can be obtained which is computed as follows [10]:

$$\text{Maximum return sludge concentration} = \frac{1.2 \times 1{,}000{,}000}{\text{SVI}} \text{ mg/l}$$

This is an equation used often in domestic sewage treatment plants with standard scraper mechanism clarifiers where the sludge is withdrawn at a center sludge well and swept into the sludge well by scraper mechanism. By using a suction type clarifier probably a factor greater than the 1.2 may be used. To make the equation dimensionally true, no factor would be used at all, but the factor, the 1.2 in the equation given, takes into account the compaction and the thickening of the sludge due to the water depth in the clarifier tank, the additional detention time in the clarifier over and above what was available in the settling test, the hydraulic overflow rate of the clarifier, and the action of the clarifier mechanism in settling the sludge and compacting it. The sludge settling tests were run for one hour during this study and 15 minutes prior to the reading at one hour the graduated cylinder in which the test was being run was rotated by hand with care being taken not to disturb the sludge blanket. The sludge settling curves for the sludge are presented in Appendix C with the sludge being allowed to settle greater than one hour to establish the curves.

During the 1968 operating season when clarification was practiced with the suction sludge removal clarifier and with the clarifier operating, the sludge being recycled was tested for concentration. The factor in the returned sludge concentration equation which would have been necessary during this entire period of time to predict the sludge concentration being recirculated from the sludge volume index as computed with one hour settling time was consistently greater than 1.2. Nearly 50% of the days in this period of time the sludge concentration experienced would have required a factor of 1.5 or greater to have been predicted. No attempt was made to have maximized this factor but on the maximum day the factor would have been 2.33. During this period, the overflow rate on the clarifier was less than 400 gallons/square foot/day. It is felt that the clarifier design including the vacuum sludge removal and low overflow rate combined to aid in increasing the return sludge concentration. A factor of 2.0 could probably be maintained on this waste treatment system with this clarifier on a consistent basis, provided that adequate dissolved oxygen and adequate nutrients are present in the system for the biological growth. It is probable that the characteristic settling curve which is quite slow for sludge developed on this waste as shown on the curves in Appendix C has a large part to do with this high compaction factor since the activated sludge from a domestic waste treatment plant compacts almost to its maximum amount within the first 1/2 hour with little compaction taking place thereafter while the biological sludge from the fruit processing waste in this system tended to continue to compact and settle even up to 6 hours or more. The volatile suspended solids averaged about 90 percent of the total suspended solids in the biological sludge which may have accounted partially for its slow settling rate. The sludge volume index during the 1968 season is plotted on Figure 42 versus the COD removal rate. There is somewhat of a trend to this data in that the SVI slopes upward from approximately 200 to 400 at COD removal rates from 0 to about 0.2 mg COD/mg VSS/day, then appears to sharply turn upward, peak, and come back down and at approximately 0.6 and begin to level off again at around 200. For all points obtained at removal rates greater than 0.6, the MLVSS was less than 1000 mg/l. Also considerable suspended solids (deflocculated sludge) remained in the supernatant. Pipes [11] observed "deflocculated" sludge in similar instances. It was in this same region of operation that inadequate nutrients were available, which probably compounded the problem. This curve is similar to curves that have been plotted by others [3] and [12] for sludge volume index versus removal rate curves. However, this curve starts much higher and peaks much higher than the curve reported by Stewart [12] where for domestic waste, the curve begins at well under 100 and peaks at less than 400 then returns to well under 100 again when the removal rate reaches

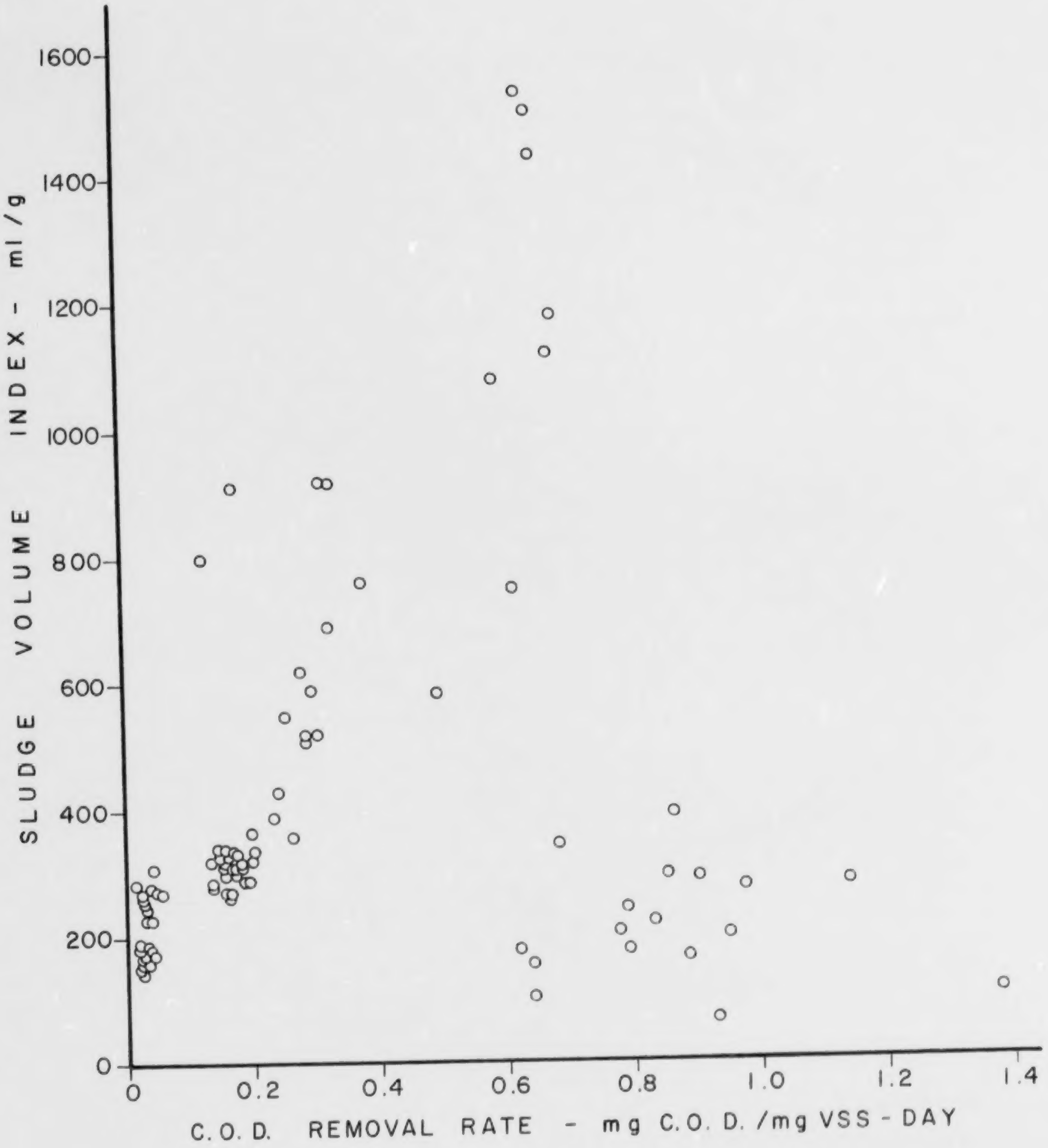

FIG. 42. — SLUDGE VOLUME INDEX VS C.O.D. REMOVAL RATE - 1968

approximately 3. Once again, the indication is that the biological sludge grown in this system on fruit processing wasts has a much slower settling rate than that for domestic waste and continues to settle well beyond a period of which the settleable solids is read in the sludge volume index computed. This makes the settleable solids test and sludge volume index much different in a fruit processing waste treatment system than in a domestic waste activated sludge system, and the interpretation and use of the data must be different also.

Sludge Wasting and Disposal

Sludge wasting is necessary from aerobic biological treatment systems such as this in order to maintain a workable system. This sludge is partially wasted over the clarifier weirs in the form of effluent volatile suspended solids. The efficiency of this system largely revolves around the amount of this sludge that is going out into the effluent. In order to prevent excessive sludge from going out into the effluent, sludge must be wasted from the system by other means. The Snokist Growers waste treatment system had designed into it sludge wasting with the use of a flotation thickener for the activated sludge. Difficulties in materials delivery and installation and the short processing season did not allow the thickener to be placed into operation during the 1968 season with the exception of a short startup trial period. This startup trial indicated that the particular system that was furnished had a deficiency in air solution capacity and this has, hopefully, been rectified since that time. It was found that the sludge was possible to thicken although a maximum concentration of sludge cake obtained was only about 2.5% during the short period of operation. Further experience will have to be gained before this can be established as a workable system of sludge disposal. Of course, the workability of this system will depend on the economics and the ability of the system to eliminate as much water as possible from the sludge to be disposed of. Thickened sludge disposal from Snokist Growers system is anticipated to be used for fertilizer or land disposal. The more concentrated the sludge can be made, the more economical will be the disposal costs since the fertilizer value lies in the solids only and not in the carriage water which must be included.

AERATION BASIN TEMPERATURE PREDICTION

In order to design a system for waste treatment using the enclosed theory and the constants obtained, it will be necessary to estimate the operating temperature of the aeration system. A rational approach to estimating a temperature under operating conditions would take into account the heat present in the incoming waste as well as the heat being lost to the environment or gained from it. If the aeration basin contents is assumed as the reference temperature then the heat being added by the incoming waste flow will be:

$$H_i = h_i\ Q(T_i - T_w)$$

H_i = Heat in the influent to the basin

Q = Flow - MGD

T_i = Temperature of waste into basin - °C.

T_w = Temperature of basin contents - °C.

h_i = Constant

The heat being lost to the atmosphere can be represented by:

$$H_a = h_a\ A(T_w - T_a)$$

H_a = Heat lost to the atmosphere

A = Surface area of aeration basin - 10^6 ft.^2

T_a = Temperature of atmosphere - °C.

h_a = Constant

Since the temperature of the effluent is the same as that of the aeration basin contents, no relative heat is lost therein. If we consider the heat loss to the ground and the heat contribution of the aerators and biochemical reactions as negligible, then to maintain an equilibrium influent heat and atmospheric heat loss must balance. The amount of aeration in operation on the lagoon would affect the constant h_a. This effect has been ignored here since the data collected on this project contains so much scatter.

$$H_i = H_a$$

$$h_i\ Q\ (T_i - T_w) = h_a\ A(T_w - T_a)$$

$$Q(T_i - T_w) = h\ A(T_w - T_a) \qquad (13)$$

where

$$h = \frac{h_a}{h_i} = \text{constant}$$

Eckenfelder [13] evaluated this constant as approximately twelve.

Equation (13) can be plotted to solve for the constant with data collected. This was done with weekly average temperatures of the influent waste stream and aeration basins studied. The weekly average waste flow was used for the plot and a weekly average of daily average temperature at the Yakima airport as collected by the U. S. Weather Bureau [14] [15]. The daily average temperature as published is not the average of hourly readings but the average of the high and low for the day. Figure 43 contains this data with h evaluated drawing the line through the origin and the median data point:

$$h = 2.5$$

As it can be seen, the data is quite erratic. The influence of the factors taken as negligible is unknown. Contributing to variance are the air temperatures at the airport, six miles away and merely the average of daily highs and lows. Residual heat in the basin at atmospheric temperature changes, and temperatures taken only on grab samples a few times a day would affect data as would the number of aerators in operation.

To estimate the temperature of a facility under design, the flow and its approximate temperature must be estimated and a proposed aeration basin surface area chosen. History of atmospheric temperatures for the locality can be found in published material.

Equation (13) can be solved for T the aeration basin temperature to yield equation (14).

$$T_w = \frac{QT_i + h\ AT_a}{Q + h\ A} \tag{14}$$

This equation can be used with h as found above or an assumed h to estimate the temperature in a proposed system.

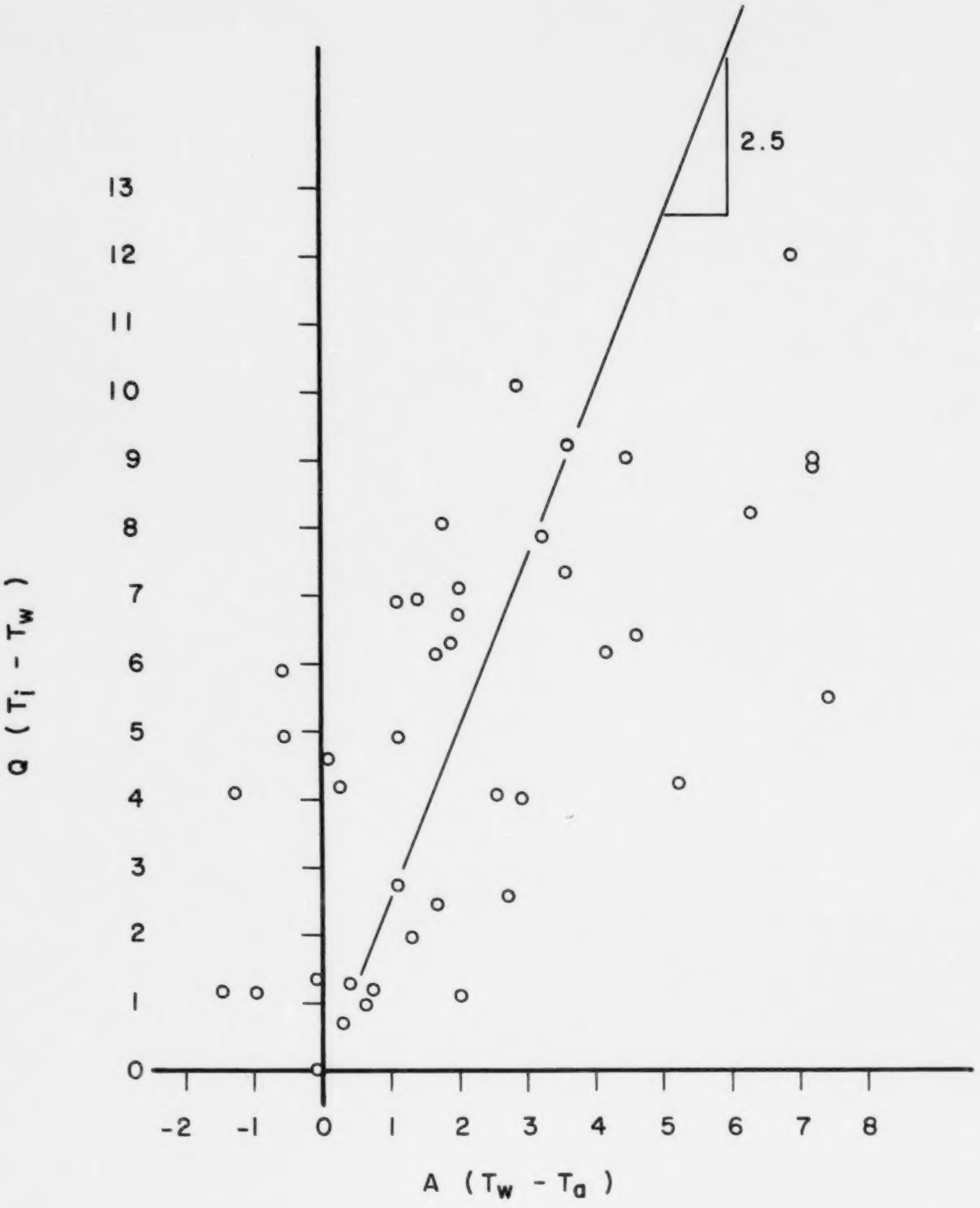

FIG. 43. — AERATION BASIN TEMPERATURE RELATIONSHIP

RECOMMENDATIONS

Future Studies

It is recommended that several areas surrounding the treatment of fruit processing waste would be desirable candidates for future studies. Further definition of the mixing and dissolved oxygen transfer efficiency and capabilities of the surface aerators would be desirable, in addition to studies as to whether or not the particular style of surface aerator affected these efficiencies.

It would be beneficial to know the cause and effect relationships which affect the settleability and compactability of the biological sludge developed on fruit processing waste. One special problem which needs to be evaluated here is the effect of nutrient content of the waste and of the biological sludge on the settling characteristics, in addition to the nutrient content effect on efficiency of treatment.

One final area of study which would be desirable is that of biological sludge removal and disposal. The removal aspect has been provided for in the form of a flotation sludge thickener, but this facility has not been tried or proven to date. The final disposal beyond thickening is a source of concern since it is not known when costs might be necessary for this disposal even if it can be established that the nutrient value of the sludge is of some value to an agricultural cropping operation.

Future Operation

The operation of the waste treatment facility at Snokist Growers in future seasons is recommended to follow roughly that which was followed during the 1968 season except that recirculation of sludge would begin immediately. The activated sludge operation would continue until the solids concentration reached a figure where clarification or sludge return facilities approached the possibility of failure to handle the load or aeration capability approached the possibility of being exceeded. At this time, (MLVSS will approximate 2,500 mg/l) the sludge would begin recirculation through the small basin where sludge reaeration would take place. Sludge wasting would begin shortly after that and continue until the end of pear processing at a rate necessary to maintain equilibrium (estimated maximum rate of 9,000 pounds dry solids per day). After apple processing begins the system will once again operate as an activated sludge system utilizing the large lagoon and clarifier with only a portion of the aerators in operation. Dissolved oxygen would be kept at 1 mg/l or above. It will be necessary to feed nutrients to the system. The rate will depend on the waste load and amount of sludge in the system and can be estimated from relationships developed herein. It can be checked by the amount of soluble ammonia and/or nitrate nitrogen and ortho phosphate soluble in the effluent. It would be necessary to have greater than 1 mg/l of either, as N or P, but some residual would be necessary to assure a properly operating system. The feed rate would be adjusted according to the residuals found.

The system can be expected to produce a few days of poor effluent quality at the beginning of each season when only 70 percent COD removal efficiency is experienced and considerable solids will be lost in the effluent. Improvement should take place so that within two weeks 90 percent removal should be obtained. This will be greatly improved upon if some biological solids exist in the system prior to full scale production.

Future Designs

If this system were redesigned, the sludge reaeration capability would be eliminated as too costly an item relative to its benefits. Its inclusion here is directly attributed to the previous existance of the small aerated lagoon. The aeration system, large PVC lined aeration basin, final clarifier and sludge return facilities, would be included in a redesigned facility. Also, a method of waste sludge dewatering for disposal would be included. Further evaluation of the flotation thickening needs to be carried out as does investigation of alternative methods.

ACKNOWLEDGEMENT

As with any study, the accomplishment of this project would not have been possible without the aid and assistance of many persons. First of all, the Board of Directors of Snokist Growers must be acknowledged for their foresight and recognition of the need for this type of project in sponsoring the application for grant funds and backing the project from its inception to conclusion. Mr. Frank Coleman and Mr. Jule Graff, general manager of Snokist Growers and project director, respectively, were instrumental in the inception of the project and keeping it functioning and on schedule throughout its course. Mr. Bill Carter and Mr. Mel Christenson, who are in charge of operations at the cannery are to be thanked for their diligence and consideration during the months of study during which at many times their operations were inconvenienced slightly and their help sought in procuring aid in construction and modification problems. Mr. Bill Root who is in charge of product quality control for Snokist Growers, assisted through his cooperation and coordination of the quality control section's efforts in order to allow the waste water research to continue unhindered.

Able advice on direction of the research and goals toward which to aim the project were offered by many on the outside. Mr. Donald Proctor of Washington State University, Mr. Walter Mercer of National Canners Association, Mr. Jerry Harper of the Washington Water Pollution Control Commission, and Mr. James Boydston and Mr. Kenneth Dostal of the Pacific Northwest Laboratory of the Federal Water Pollution Control Administration are all to be thanked for their assistance and suggestions during the course of this project.

All of the results of testing from the project which are presented in this report and in earlier data releases are a result of the laboratory operation which was overseen and directed by Mr. Herbert H. Hart of Snokist Growers. Mr. Hart also acted as chief operator of the treatment facilities and the day-to-day operation of the facilities was his responsibility. He was assisted in his laboratory work by Nina Wright and Jeanne Holdridge during the 1968 processing season and by Irma Rosseau and Harold Ayers during the 1967-1968 season. Assistance in sample collection was gained from Donald Brown, Donald Steveson, Vernon Henderson, and Robert Calhoun during the course of the study.

The principals and staff of Gray & Osborne were all helpful in their suggestions and aid in working on various phases of the project. Mr. John Poston was of considerable help in the design and construction phases of the project facilities. Mr. Lyle Rayburn did considerable work during the design and acted as the resident inspector during construction and subsequent to the data collection, accumulated data and drafted most of the figures present in the report. Elaine Hews and Mary Buchanan have been very understanding and diligent in their attempts to decipher the many complicated terms and expressions presented in data reports, monthly reports, and the final report for the project, and their placement into context.

Many other unnamed persons provided services and assistance during the course of the project who are too numerous to name here. Each of them provided an essential service during the study of this problem.

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APPENDIX

APPENDIX A

CONSTRUCTION & OPERATION

Appendix A contains tables summarizing the construction and operation costs of the Snokist Growers treatment facility and a list of major equipment used and manufacturers of the equipment items. Also in this section on Figures A-1 through A-7 are pictures of the treatment facilities.

Figure A-1 shows the large aeration basin in the summer of 1968 during construction activities when the center aerator (150 HP) was being installed. The 0.020" PVC liner can be seen on the dike slopes although the liner and its rock cover on the bottom are covered by water. Figure A-2 shows a more complete view of the treatment facility while Figures A-3 and A-4 show the aerators in operation on the small and large lagoons, respectively. The clarifier in Figure A-5 accomplishes final removal of suspended solids from the effluent. The mechanism in the clarifier contains vacuum sludge removal manifolds which rapidly pick up the settled solids. The solids are then returned to the aeration basin via the sludge return pumps shows in Figure A-6. Sample testing for the study and for control of the waste treatment system is done in the laboratory pictured in Figure A-7.

TABLE A-1

COSTS OF CONSTRUCTION OF TREATMENT FACILITIES

I. CONSTRUCTION PRIOR TO BEGINNING OF R & D PROJECT

A. Original Construction - 1964

1. Small Lagoon Construction - 236' x 136' x 8' Deep	$13,801.21	
2. Asphalt Lagoon Lining - Blown in Place	4,606.11	
3. Two 30 HP Surface Aerators	16,681.60	
4. Aerator Supports, Walkways and Installation	7,720.26	
5. Aerator Electrical	3,541.68	
6. Lagoon Piping	3,381.44	
7. Outfall to Yakima River - 1685' of 18" and 15" Concrete Pipe	13,393.27	
8. Fencing - 1170' Chain Link	2,153.32	
9. Miscellaneous	2,295.66	
10. Engineering	7,357.77	$74,932.32

B. Rectangular Settling Tank - 1966

1. Steel Tank - Complete with accessories- Installed		24,830.26
TOTAL		$99,762.58

II. CONSTRUCTION FOR AND DURING R & D PROJECT

A. Aerated Lagoon - 1967

1. Lagoon Construction - 277' x 280' x 12.5' Deep	$15,200.93	
2. PVC Lagoon Liner - Installed with Rock Cover*	34,229.64	
3. Lagoon Influent and Effluent Structures and Aerator Footing	12,845.60	
4. Four 60 HP Surface Aerators	41,760.71	
5. Aerator Installation	3,934.24	
6. Aerator Walkways	11,027.08	
7. Aerator Electrical	3,633.91	
8. Lagoon Piping	10,342.10	
9. Fence - 1540' Chain Link	5,159.00	
10. Miscellaneous	2,530.95	$140,664.16

* Including Snokist's Costs Incurred for 1968 Repair and Reconstruction.

TABLE A-1 - Continued

B.	Clarification and Sludge Return, Added Aeration, Thickener - 1968			
	1.	Sludge Return Pipe and Aerator/ Walkway Footings	$ 5,258.50	
	2.	Variable Speed Sludge Return Pumps - Two - 1750 GPM	6,888.00	
	3.	150 HP Surface Aerator	23,950.00	
	4.	Suction Clarifier Mechanism - 90' Diameter	21,460.00	
	5.	Flotation Sludge Thickener Equipment	28,590.00	
	6.	Pump Building - 24' x 30'	6,200.00	
	7.	Clarifier Structure - 90' Diameter x 9' SWD and Mechanism Installation	58,200.00	
	8.	Aerator Installation and Aerator Walkway	5,020.00	
	9.	Thickener Appurtenances and Installation	15,800.00	
	10.	Piping and Flow Control Structures	22,069.40	
	11.	Influent and Sludge Flow Meters	2,800.00	
	12.	Thickened Sludge Pump and Piping	7,850.00	
	13.	Electrical and Controls	14,800.00	$218,885.90
C.	Laboratory			
	1.	Building - 36' x 22' with Heating, Plumbing, Electrical	$19,175.00	
	2.	Cabinets, Counters and Flume Hood	9,667.04	28,842.04
D.	Engineering			
	1.	Preliminary Planning	$ 6,954.81	
	2.	Plans and Specifications	25,313.54	
	3.	Construction Services	13,139.36	45,407.71
E.	Laboratory Equipment			
	1.	Drying Oven	$ 240.45	
	2.	Muffle Furnace	291.55	
	3.	Analytical Balance	804.65	
	4.	Dissolved Oxygen Meter	470.25	
	5.	BOD Incubator	548.62	
	6.	Kjeldahl	1,722.16	
	7.	Distillation Apparatus	574.75	
	8.	pH Meter	674.03	
	9.	Colorimeter-Spectrophotometer	412.78	
	10.	Miscellaneous Equipment and Glassware	3,856.24	9,595.48
		TOTAL - 1967-1968 CONSTRUCTION		$443,395.29
		TOTAL COST OF TREATMENT FACILITY		$543,157.87

TABLE A-II

MANUFACTURERS OR SUPPLIERS OF MAJOR EQUIPMENT*

EXISTING FACILITIES

1.	Vibrating Screens - 2 each	Link Belt Company
2.	Surface Aerators - 2-30 HP	Infilco
3.	Lift Pumps and Sludge Return Pump	Wemco

1967 CONSTRUCTION

1.	Aeration Basin PVC Lining .020 In.	Staff Industries
2.	Surface Aerators - 4-60 HP	Eimco Corporation
3.	Flow Meter and Recorder	Leupold & Stevens

1968 CONSTRUCTION

1.	Surface Aerator - 1-150 HP	Eimco Corporation
2.	Clarifier Mechanism - 90 feet Diameter Suction Type	Eimco Corporation
3.	Sludge Return Pumps - 2-1750 GPM	Chicago Pump Company
4.	Sludge Pump Variable Speed Drives	Furnas
5.	Sludge Flow Meters - Propeller Type	Rockwell
6.	Flotation Sludge Thickener	Eimco Corporation
7.	Thickened Sludge Pump	Moyno Pump Division Robbins & Meyers
8.	Laboratory Equipment	Van Waters & Rogers
9.	Dissolved Oxygen Monitor	Weston & Stack

LABORATORY EQUIPMENT*

1.	Analytical Balance	Mettler
2.	Dissolved Oxygen Meter	Yellow Springs Instrument
3.	B. O. D. Incubator	Fisher
4.	Kjeldahl Unit	Labconco
5.	Distillation Apparatus	Corning
6.	pH Meter	Fisher
7.	Colorimeter Spectrophotometer	Bausch & Lomb

*Note: Trade names are for information only and do not constitute an endorsement of the equipment by the FWPCA nor the author.

TABLE A-III

COST OF OPERATION OF TREATMENT FACILITY

1967-1968 OPERATING SEASON

1.	Electrical Power	$ 6,370	
2.	Nutrient Chemicals	10,530	
3.	Supervision & Operation	10,868	
4.	Maintenance Labor	1,332	
5.	Maintenance Materials	630	
6.	Laboratory Technicians	5,250	
7.	Laboratory Chemicals and Equipment	2,750	$37,730

1968 OPERATING SEASON

1.	Electrical Power	$ 9,040	
2.	Nutrient Chemicals	10,742	
3.	Supervision and Operation	11,730	
4.	Maintenance Labor	1,262	
5.	Maintenance Materials	630	
6.	Laboratory Technicians	4,700	
7.	Laboratory Chemicals and Equipment	2,280	$40,384

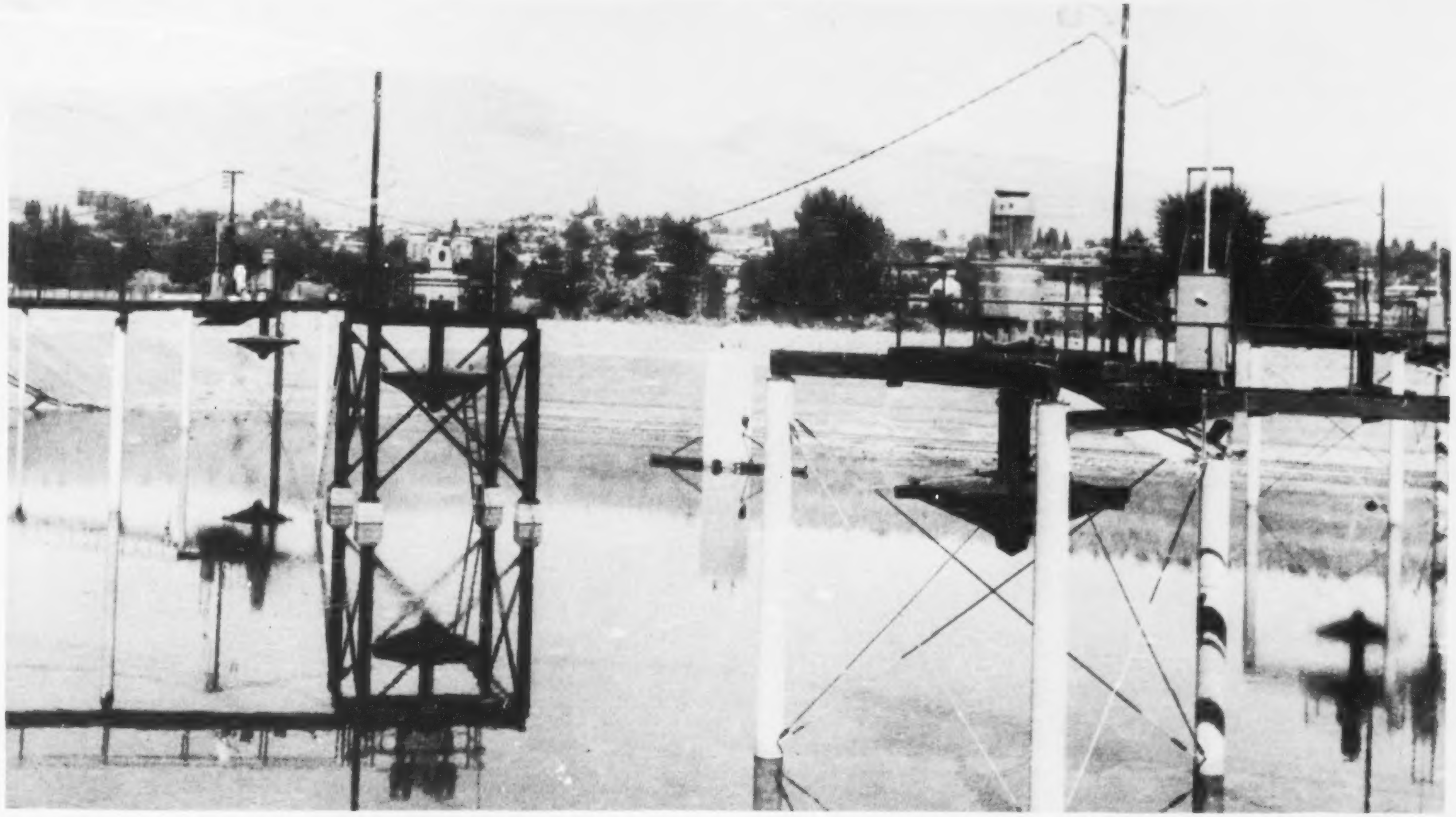

FIG. A-1. — LARGE AERATION BASIN SHOWING THREE OF THE FOUR 60 H.P. AERATORS, 150 H.P. AERATOR, P.V.C. LINING ON DIKE, AND INFLUENT STRUCTURE.

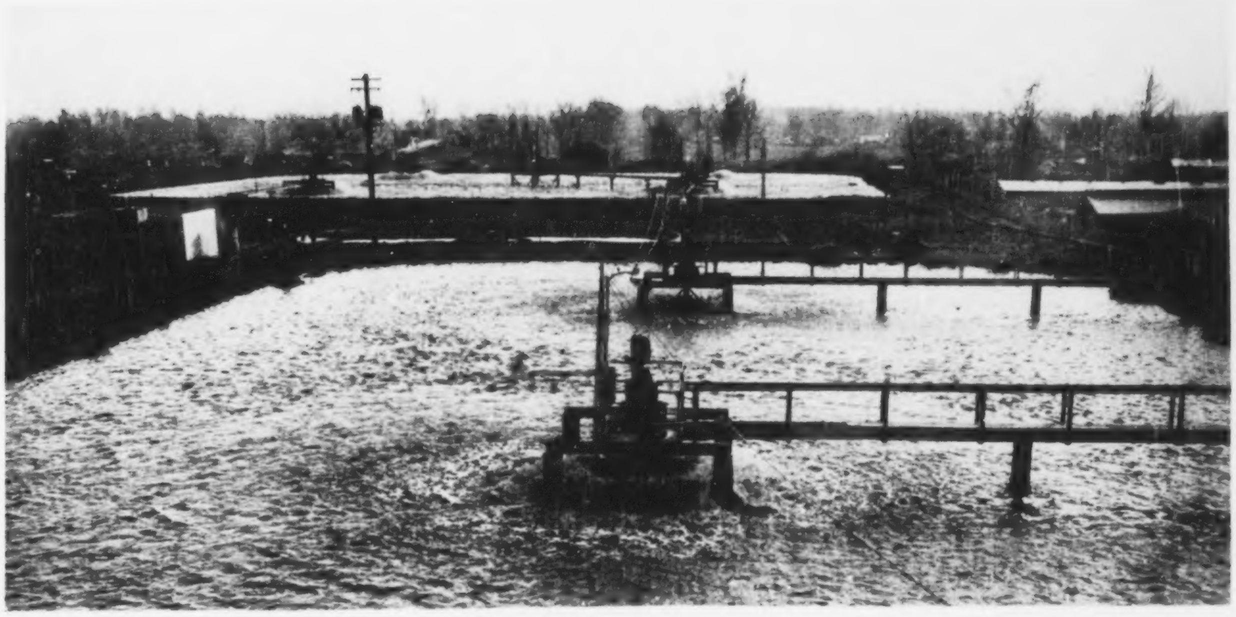

FIG. A-2.— WASTE TREATMENT SYSTEM FROM SCREENING STATION PLATFORM.

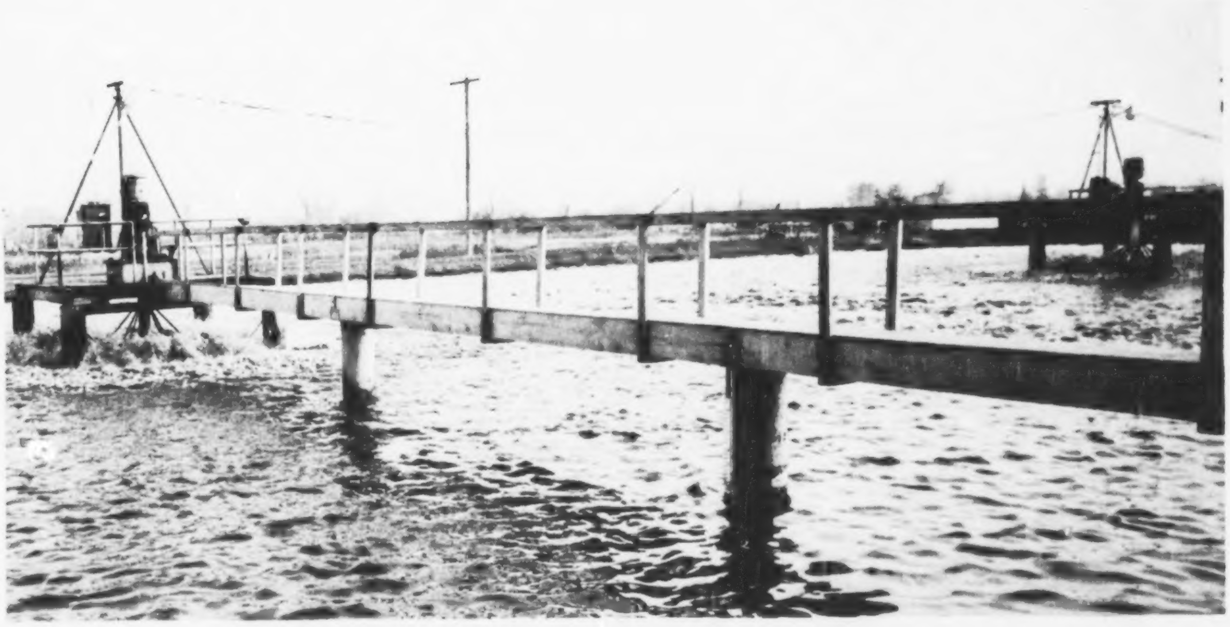

FIG. A-3. — 30 H.P. AERATORS IN SMALL AERATION BASIN.

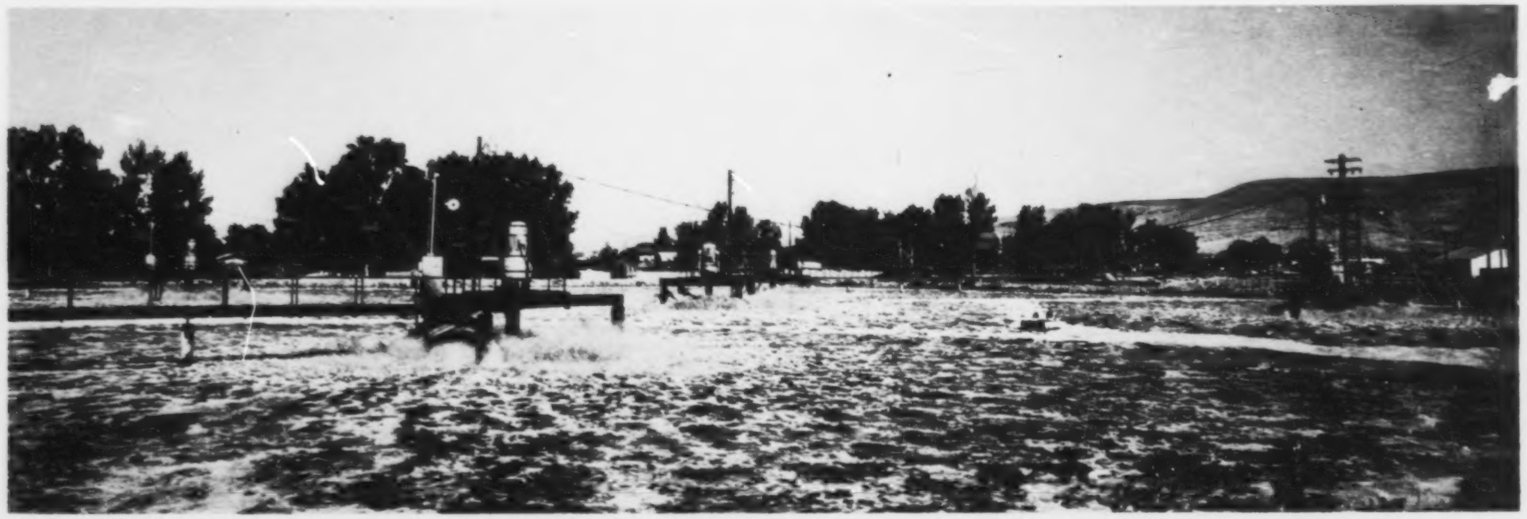

FIG. A-4. — LARGE AERATION BASIN - AERATORS OPERATING.

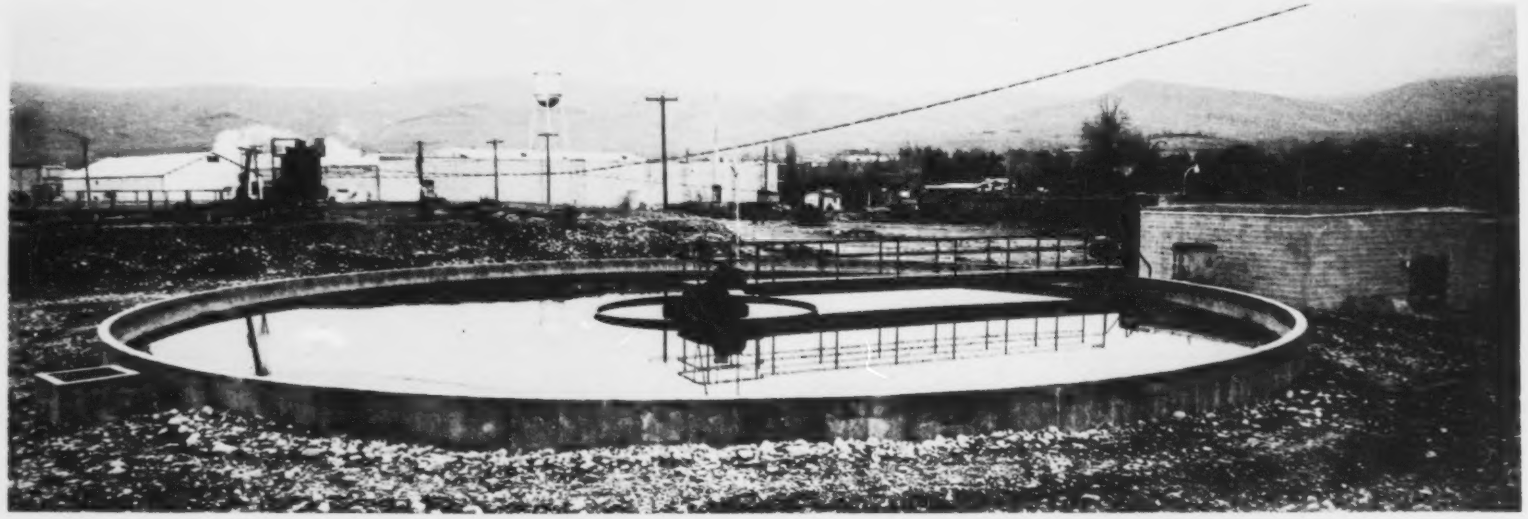

FIG. A-5. — FINAL CLARIFIER; SMALL LAGOON, SCREENING STATION, CANNERY BUILDINGS AND SLUDGE PUMP BUILDING IN BACKGROUND.

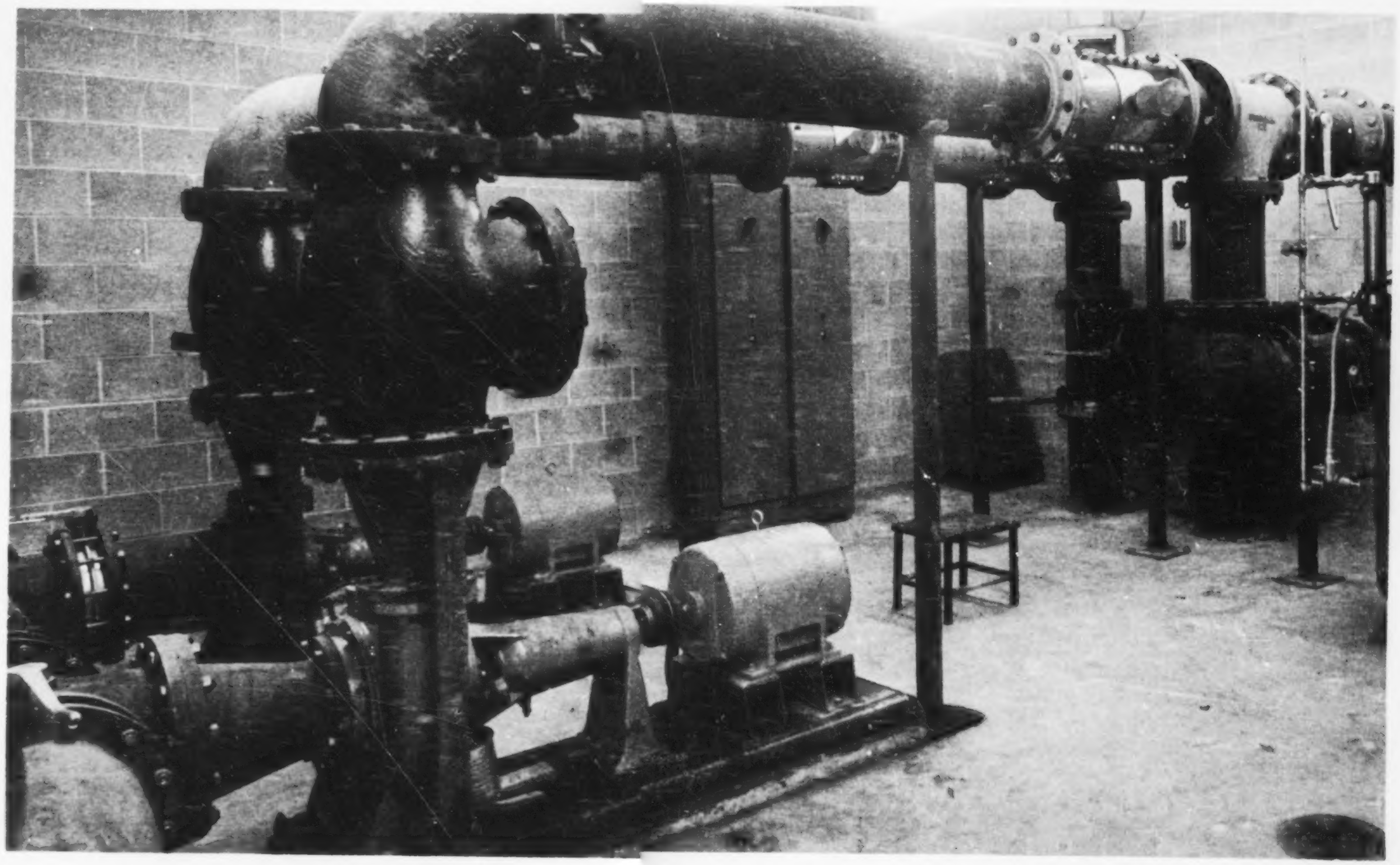

FIG. A-6. — SLUDGE RECIRCULATION PUMPS AND PIPING IN SLUDGE PUMP BUILDING.

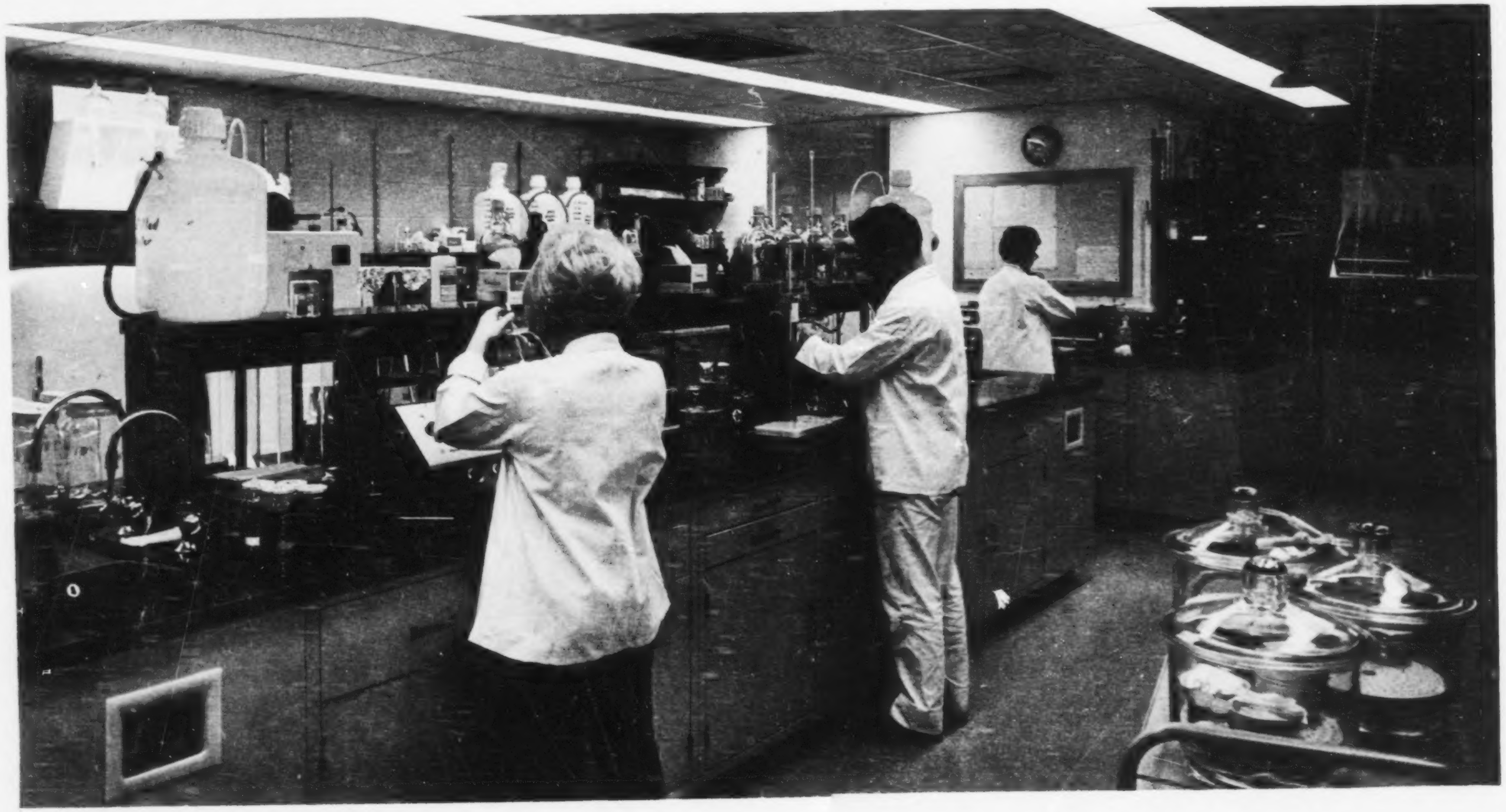

FIG. A-7. — WASTEWATER LABORATORY INTERIOR.

APPENDIX B

SAMPLING AND TESTING

Sampling during each of the two processing seasons over which the project extended was done by hand. Composite samples were taken during the processing day on the screened influent to the treatment systems, on the effluent from the aeration basin, and on the effluent from the clarifier and on the return sludge from the clarifier when the clarifier was in operation. Grab samples were taken periodically of the aeration basin contents for settling tests and suspended and volatile suspended solids tests.

The flow from the cannery was metered over a two foot rectangular weir and integrated with the use of a water level recorder which recorded the water height falling over the weir crest. The flow when split between the two aeration basins was done by a divider plate being positioned in front of the weir which split the flow between the influents to the two aeration systems. Changes in this divider plate position were recorded in order to get an accurate record of the flow disposition. During the second year of operation when a totalizer was added to the water level recorder, the totalizer was read daily in addition to the flow chart being integrated manually.

Sample Compositing, Storage and Preservation

The hand taken samples were composited on approximately an equal basis throughout the operating day since on any particular operating day the flow did not vary greatly from the cannery and was considered to be even enough to allow this method of compositing. Samples were not taken during the washup period which usually occurred between midnight and seven a.m. in the morning. It was determined, through successive trial calculations that the total daily load of BOD and COD in the waste from the cannery could be determined by using the concentrations found from testing of the composite samples collected during the processing day and over a flow total which included the flow during processing itself and for an additional two hours per day. This two hours included time between shifts and down time during shifts. As an example, if two shifts were run per day beginning at 7 a.m. and extending until midnight during which sixteen hours of actual processing occurred, the flow to be used for computation of waste load would extend from 7 a.m. to 1 a.m. the following day, or 18 hours as opposed to the 16 hours of actual processing. Figure B-1 shows typical daily flow records.

During the 1967-1968 processing season, a temporary laboratory was necessary in order to accomplish the testing program since the new laboratory was not yet constructed. Since the facilities were limited in this temporary laboratory, it was attempted to preserve samples for later testing by placing the samples in No. 2-1/2 or No. 303 cans and running them through the same process as produce cans where lids were placed on them and the cans were sterilized.

It was anticipated that such tests as BOD, COD, nitrogen, phosphorus and total volatile solids could be performed on these canned samples. The test for total volatile solids and nutrients was apparently valid from these samples although it appeared that the BOD and COD values could have changed somewhat due to the preservation, especially in samples containing suspended solids. In addition, it was only the total nitrogen and phosphorus tests which were valid since the organic nitrogen and organic phosphorus was partially broken down into ammonia nitrogen and phosphates due to the canning process which involved a high heat for sterilization. This caused difficulty in allocating nitrogen and phosphorus values to the biological solids in the sample. As a result of this experience, it is recommended that in future studies this method of sample preservation not be utilized with the exception of perhaps on the raw waste where nutrient values and total solids might be concerned. The BOD values obtained from the preserved samples along with data from fresh samples were used in plotting Figures 4 and 7. It was not necessary to use COD data from the preserved samples since adequate analyses were run on fresh samples.

During the second season of operation, due to some difficulties with apparatus for a short time, some samples were frozen for preservation for later testing. Only three sets of samples were handled in this manner and on these sets of samples only nutrient values were obtained from the testing with the exception of one sample set where BOD's were necessary. An additional set of samples upon which analysis had been done on fresh samples were also frozen to act as a pilot. The BOD as determined from the frozen sample was not the same as the BOD's found on the original sample and consequently the frozen sample BOD's were not considered usable. This is especially true of the biological effluent from the treatment system where the BOD contributed to by the volatile suspended solids was increased. There did not appear to be any alteration of nutrient values or of shift in the forms of nitrogen or phosphorus due to the preservation by freezing.

pH

The pH was measured electrometically, standardized to 25° C. utilizing a glass electrode on fresh grab samples from the treatment systems [B-1]. The pH as recorded for the influent was an average of 2 or 3 grab samples during the processing day.

Settleable Solids

Settleable solids were measured using 1,000 milliliter graduated cylinders or, in the case of clarified effluents, one liter settling cones. Readings for settleable solids were taken in one hour and to produce the settling curves at one hour intervals thereafter.

Suspended and Volatile Suspended Solids

Suspended and volatile suspended solids analyses were run by filtering the sample through a grade GFC glass-fiber filter which was designed to retain particles in a semi-colloidal range. This glass filter paper was pre-washed in a diluted acid solution and in distilled water, fired in the muffle furnace and tared prior to filtering the sample with the use of a vacuum filtration apparatus. The filter was then dried and weighed for a total suspended solids determination. The filter and residue following firing in a muffle furnace at 550° C. was cooled and weighed again to determine the fixed solids and the volatile solids by difference. This method is as described by D. Jenkins [B-2].

Total Solids and Total Volatile Solids

Total solids were determined by drying a sample in a tared drying dish and reweighing. The total volatile solids were determined by the difference between the dry solids reading and the weight following ignition at 600° C. in a muffle furnace [B-1].

Chemical Oxygen Demand (COD)

The COD determination was done by the method described in Standard Methods [B-1] using potassium dichromate as an oxidizing agent. One modification was made in the procedure as described by Standard Methods, that being that 10.0 ml of sample or less was used and 20.0 ml of standard potassium dichromate solution was used to reduce the amount of dilution of the samples.

Biochemical Oxygen Demand (BOD)

The BOD determinations were performed according to Standard Methods [B-1]. The waste treatment system effluent was used for seed for the raw waste and when it was available,on preserved samples. Seeding was done on other preserved samples by using the effluent from the Yakima City Sewage Treatment Plant for seed material.

Dissolved Oxygen

The dissolved oxygen was measured with the use of a dissolved oxygen probe and analyzer calibrated in air prior to use. Temperatures in the lagoon were also taken with this analyzer and a thermistor probe. (Appendix D contains a further discussion of this meter).

Ammonia Nitrogen

Ammonia nitrogen was determined by distillation and titration of the distillant with H_2SO_4 as outlined in the 12th Edition of Standard Methods [B-1].

Organic Nitrogen

The organic nitrogen determination was made according to Standard Methods [B-1] using the Kjeldahl method. The samples which were earlier distilled for ammonia determination were digested in acid solution and then the ammonia nitrogen was distilled off and determination was made for ammonia nitrogen on the distillate.

Nitrate Nitrogen

Nitrate nitrogen was determined Spectrophotometrically using Brucine as outlined by Krawczyk [B-3] and Jenkins and Medsker [B-4].

Orthophosphate

Orthophosphate was determined in accordance with Standard Methods 12th edition [B-1]. The Stannous chloride method was used utilizing extraction into Benzene-isobutanol.

Total Phosphate

Total phosphate was determined according to Standard Methods [B-1] which utilized boiling the sample in acid solution and subsequent analysis for orthophosphate.

Total Phosphorus

Total phosphorus which includes ortho and total phosphate in addition to organically bound phosphorus was determined utilizing a method used at the Sanitary Engineering Research Laboratory of the University of California in Berkeley [B-5]. This determination consists of alkaline ashing of the sample at 800° C. followed by determination of the phosphorus utilizing strong acid molibdate reagent, heating on a steam table to attain reaction. Color development is done using Aminonaphtholsulfonic acid or Stannous chloride reducing agent. Color reading is then done on a Spectrophotometer and comparison made with a standardization curve.

Oxygen Uptake Rate

The method for determining oxygen uptake rate is presented in Appendix D.

Supernatant and Settled Sludge Samples

Testing was done on a portion of the aeration basin samples and effluent samples on the basis of the supernatant and settled sludge from the samples. This supernatant and settled sludge was obtained by taking a composite sample or grab sample from the station and allowing to set overnight in a refrigerator.

Supernatant is drawn off the top of the sample the following day and the sludge from the bottom was tested as a settled sludge sample. The intermediate portion where the sludge and supernatant were partially mixed was discarded. Testing of these samples was done in order to determine the nutrient content of the biological solids and the remaining dissolved constituents in the waste.

REFERENCES

[B-1] Standard Methods for the Examination of Water and Wastewater, 12th Edition, American Public Health Association, Inc., New York, N.Y. 10019

[B-2] Jenkins, D., "An Improved Volatile Solids Determination," Water and Waste Treatment Journal (London) August/September, 1962

[B-3] Krawczyk, D. F., "Phosphorus and Nitrogen Analysis for Wastewater Treatment Plant Control", Pacific Northwest Water Laboratory, Corvallis, Oregon February 7, 1968

[B-4] Jenkins, D. and L. L. Medsker, "Brucine Method for Determination of Nitrate in Ocean, Estuarine and Fresh Water", Analytical Chemistry, 36, 610 (1964)

[B-5] Menar, A. B., Private Communication, January 9, 1968

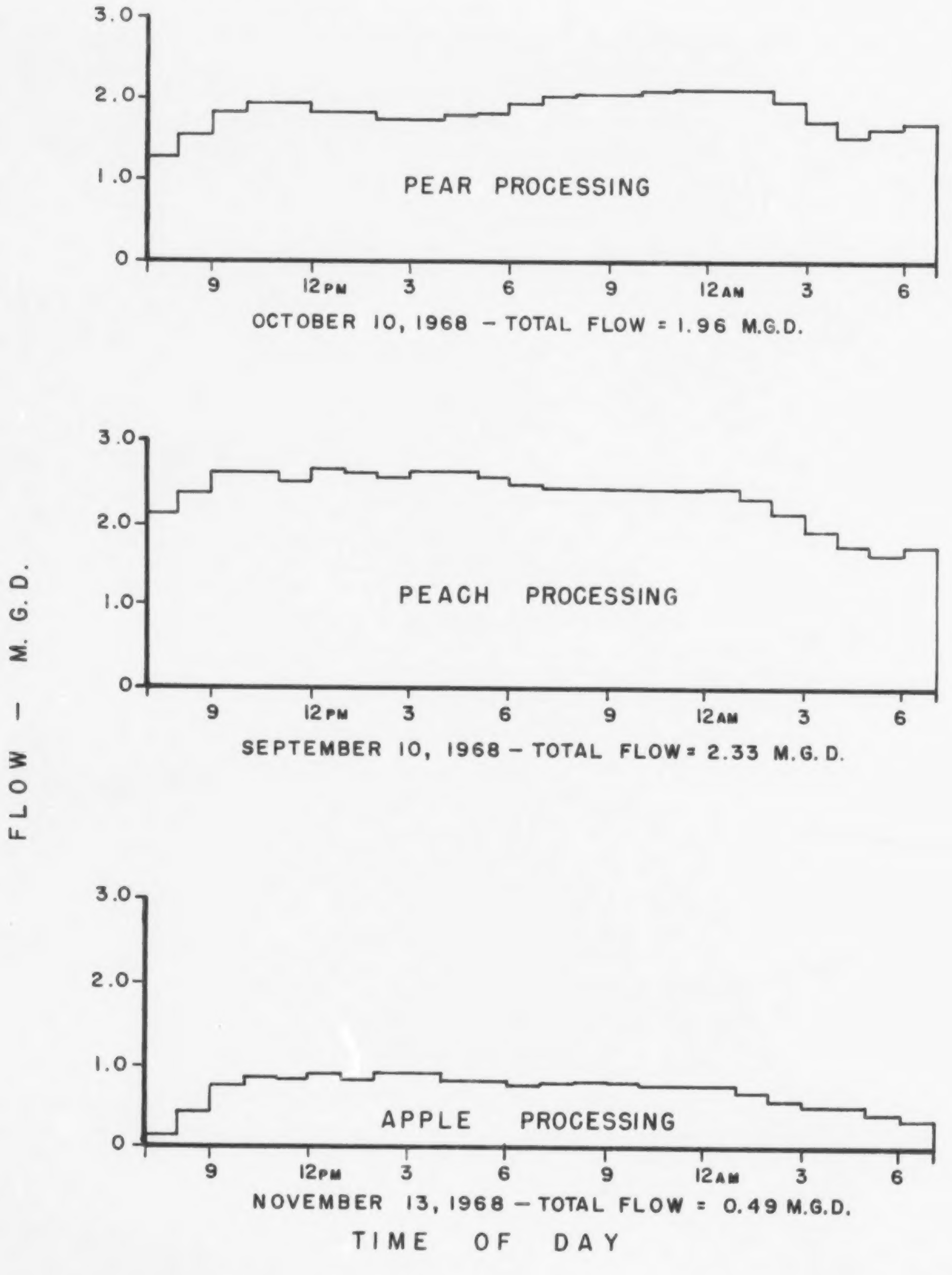

FIG. B-1 — TYPICAL DAILY PROCESSING FLOW

APPENDIX C

This appendix contains the sludge settling curves as plotted from data taken during the two operating seasons of this project. These settling curves are the result of hourly readings of the top of the sludge layer in 1,000 milliliter graduated cylinders following the placement of the aeration basin contents into the cylinder. Fifteen minutes prior to each reading, the cylinder was rotated back and forth approximately 120 degrees by hand with care being taken not to disturb the contents of the cylinder enough to resuspend portions of the solids which were or had been settled out. The reason for this action was to dislodge any particles which may have been clinging to the cylinder walls and to give a small amount of motion to the liquid in an effort to get the floc particles to compact more fully.

The dates when the samples were taken and the curves observed are given on each individual plot. During the 1967-1968 season when two treatment systems were in operation, the data points are identified on the figures. Figures C-1 through C-8 contain curves from data collected during the 1967-1968 processing season. Figures C-9 through C-14 represent data accumulated during the 1968 processing season.

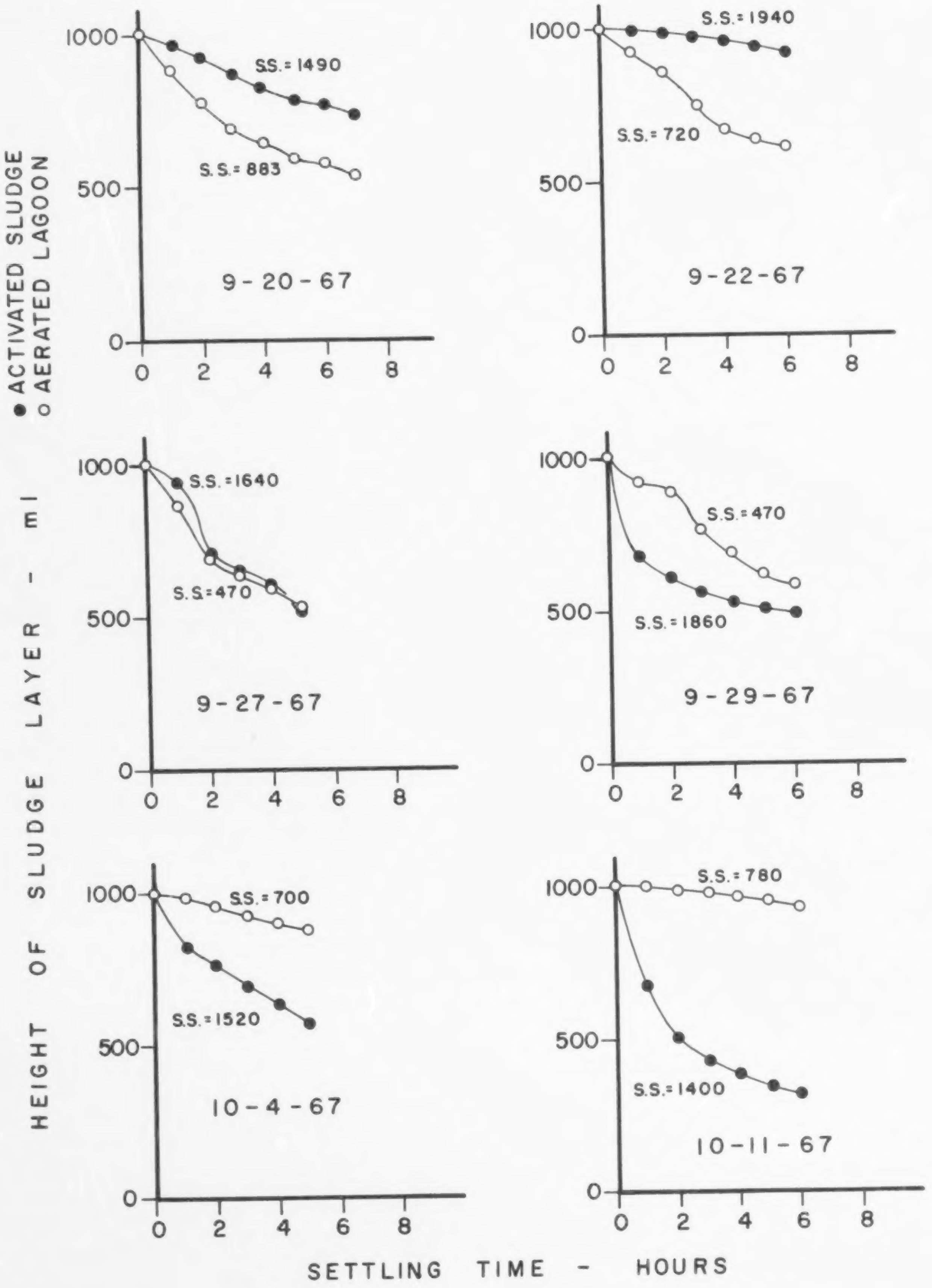

FIG. C-1. — SLUDGE SETTLING CURVES

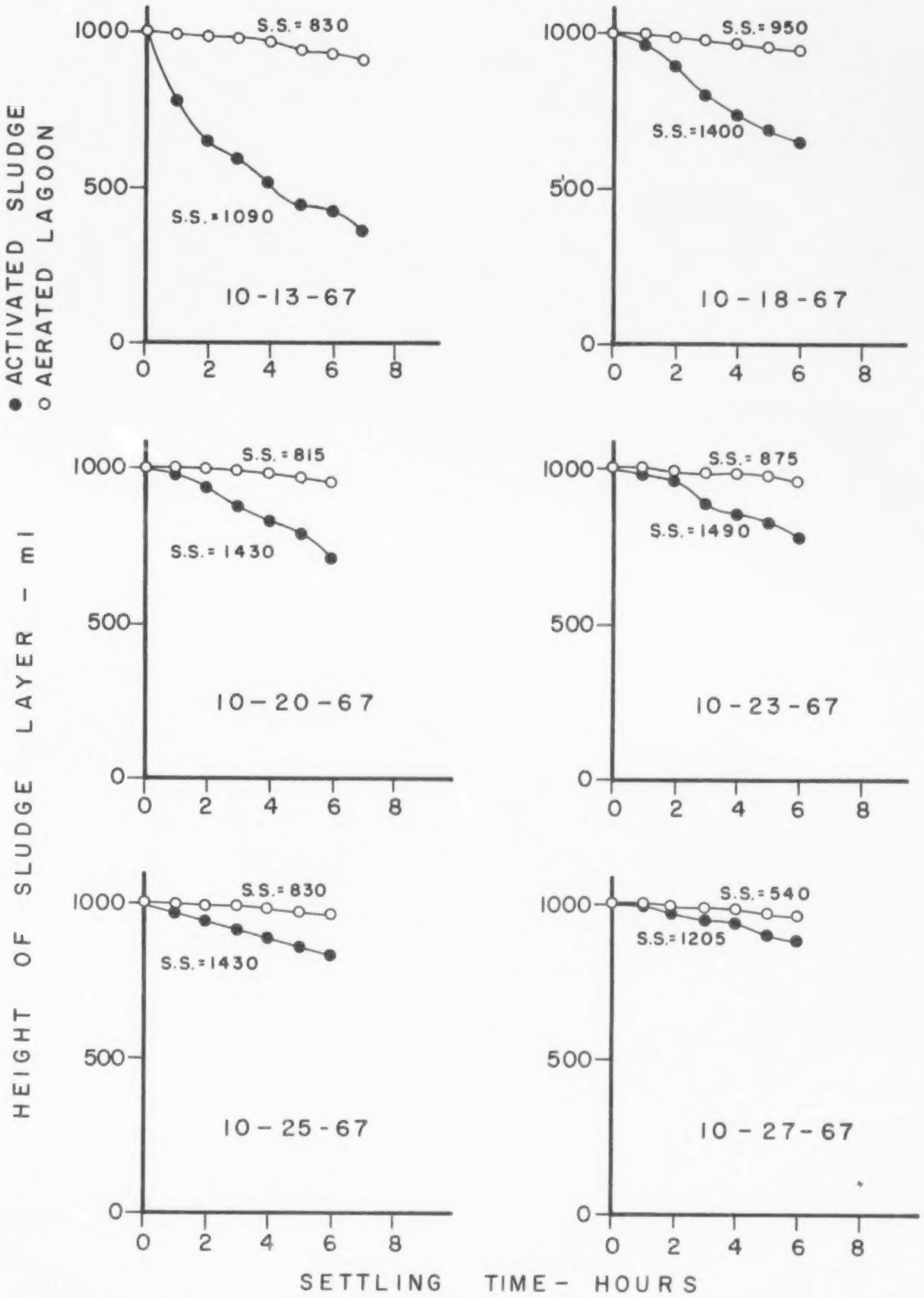

FIG. C-2. — SLUDGE SETTLING CURVES

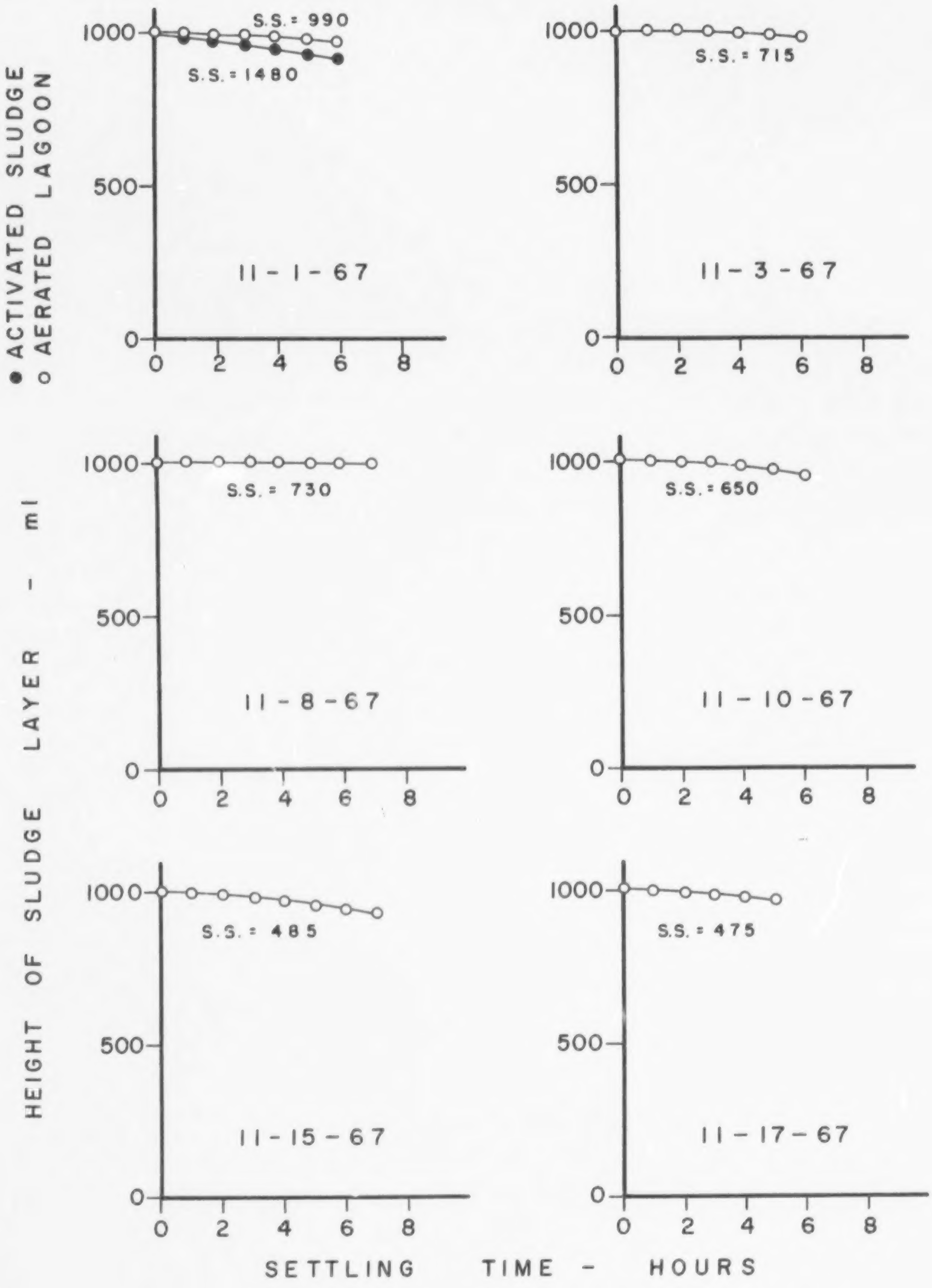

FIG. C-3. — SLUDGE SETTLING CURVES

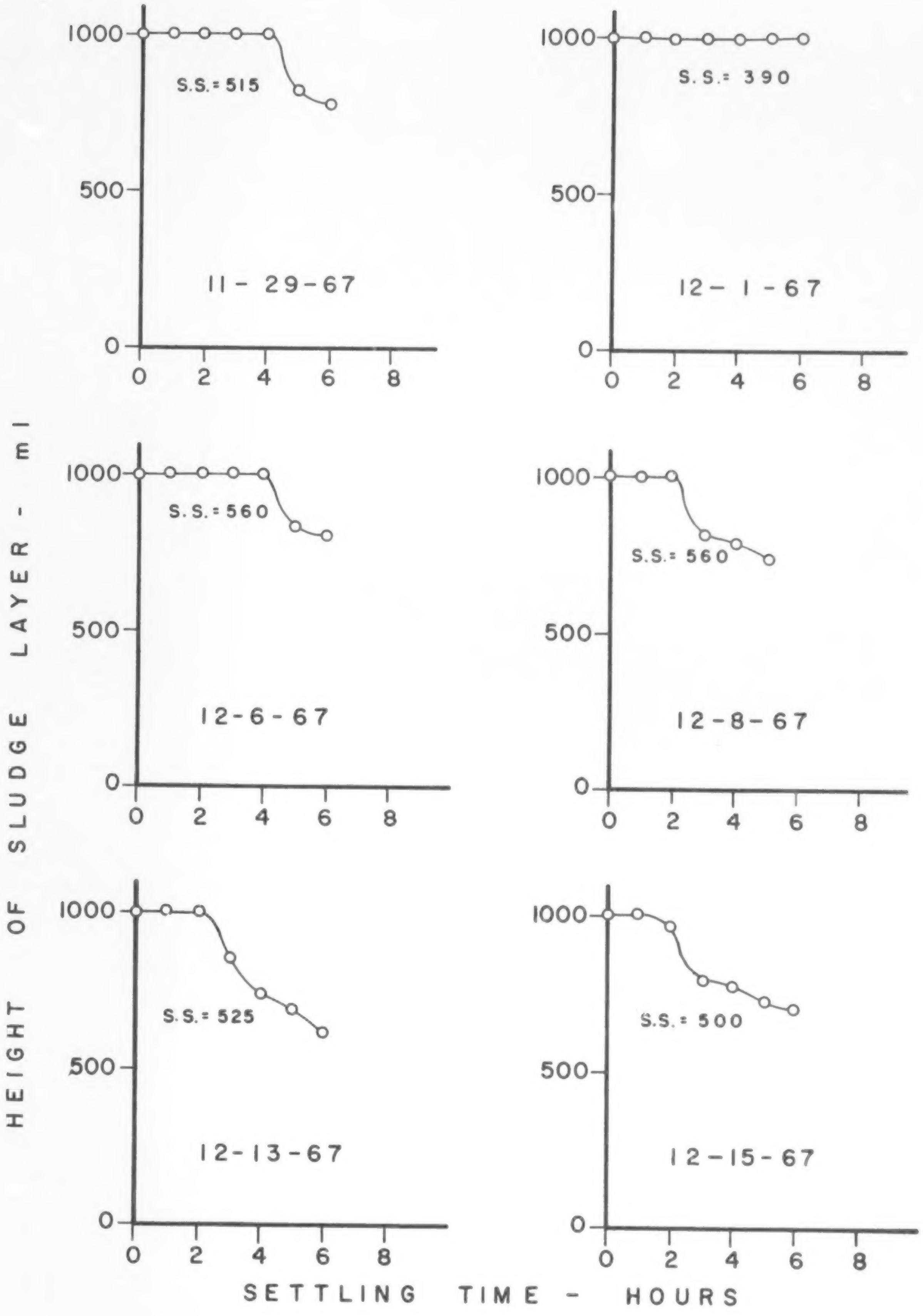

FIG. C-4.—SLUDGE SETTLING CURVES

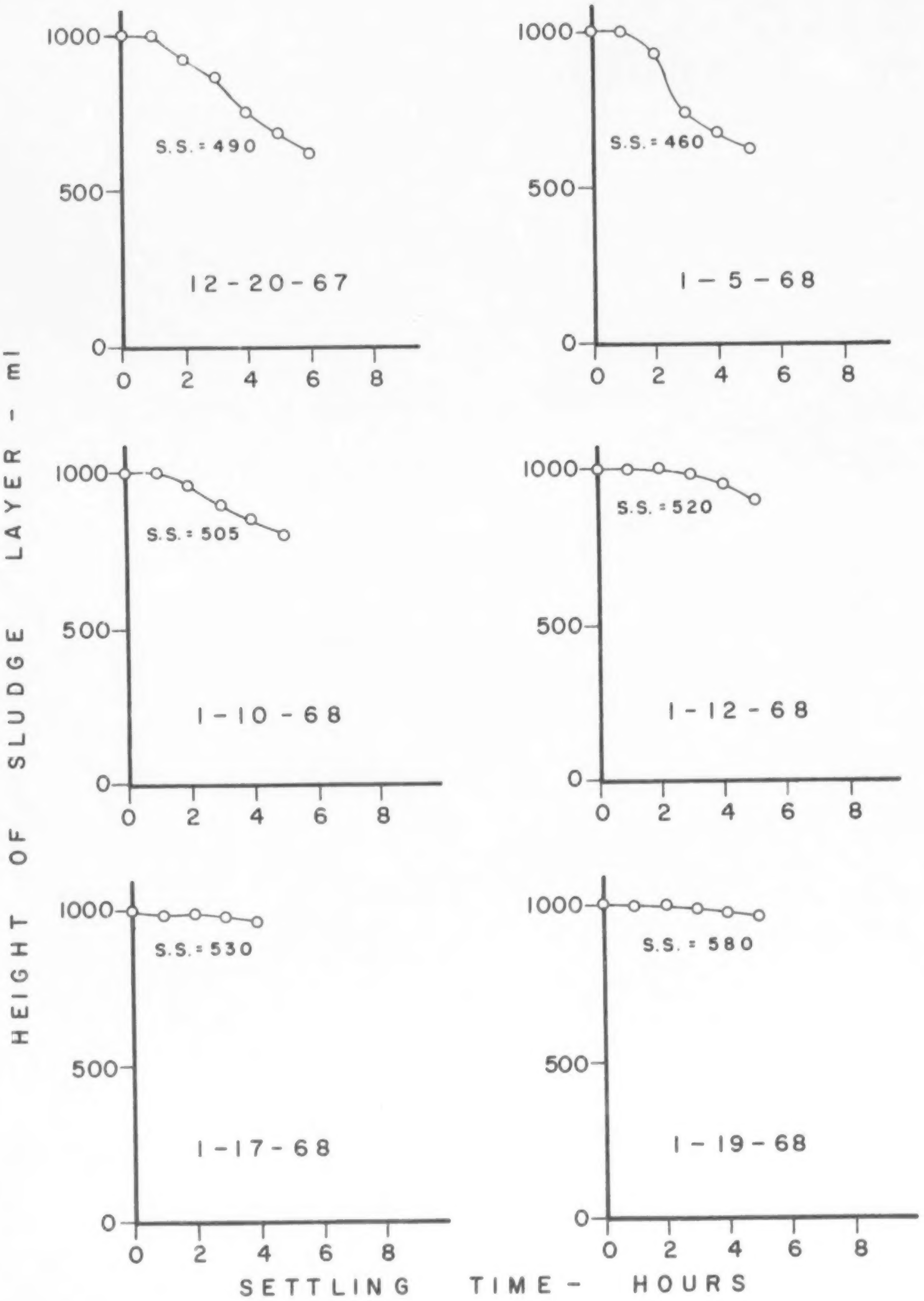

FIG. C-5. — SLUDGE SETTLING CURVES

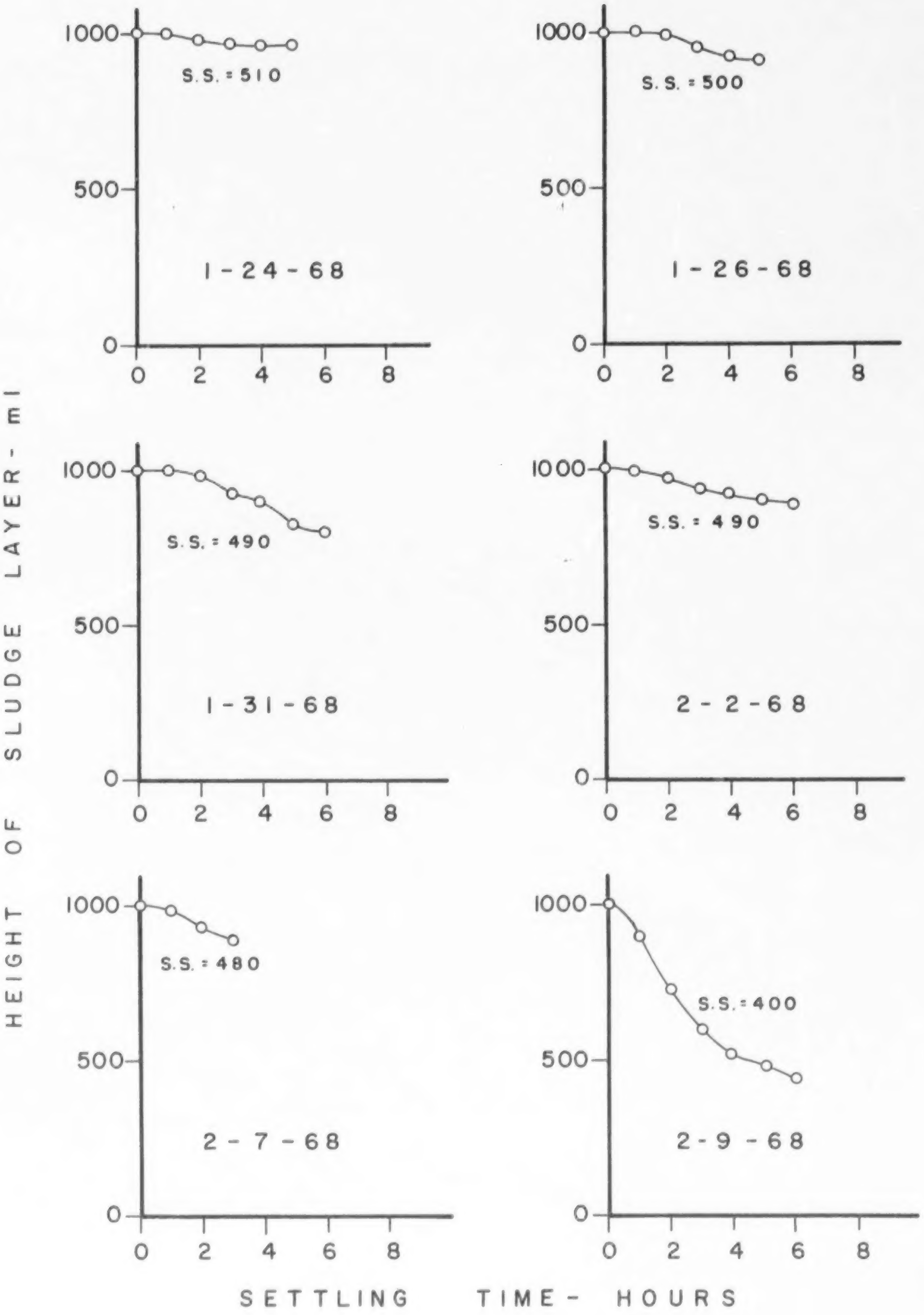

FIG. C-6. — SLUDGE SETTLING CURVES

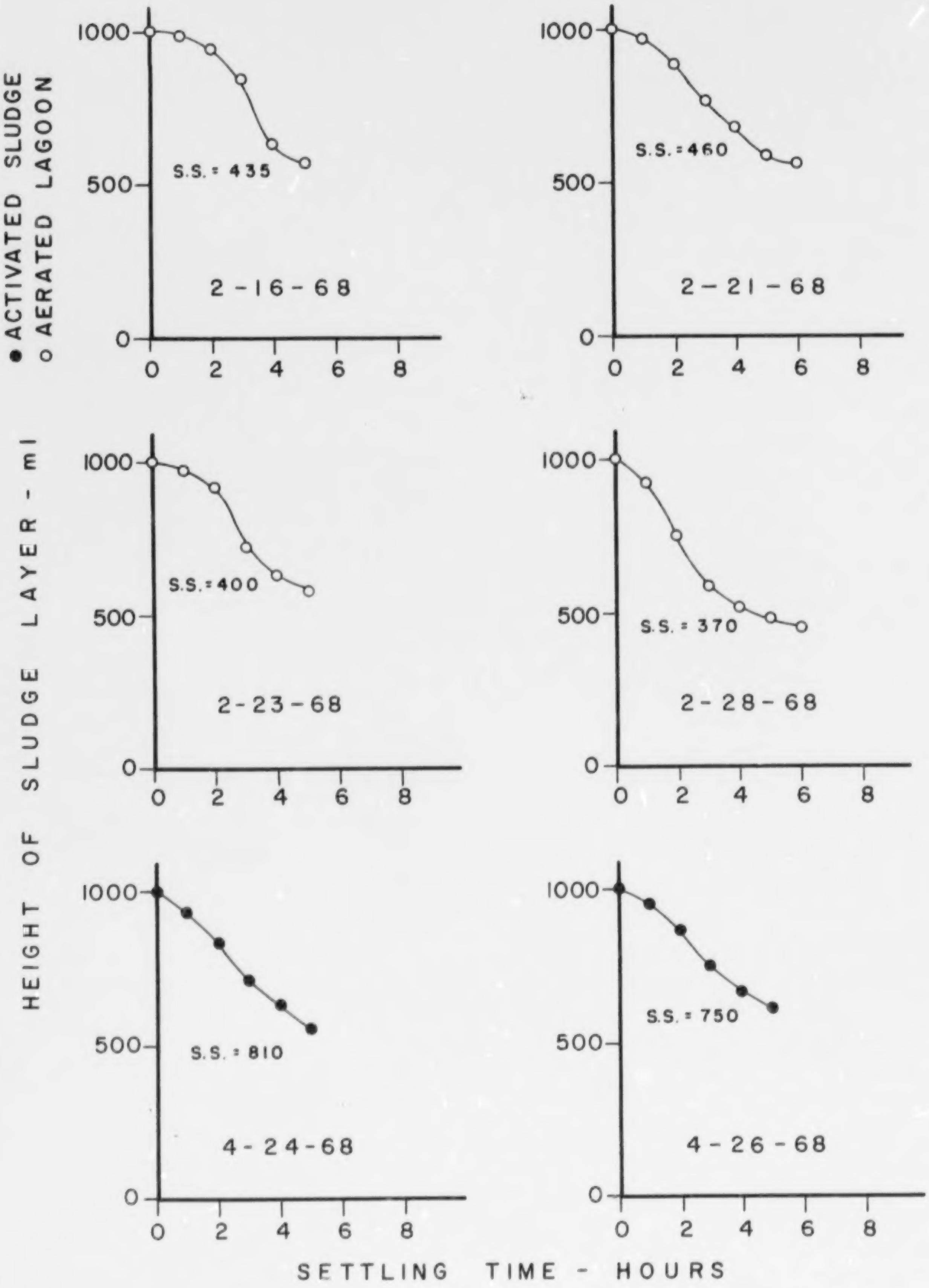

FIG. C-7. — SLUDGE SETTLING CURVES

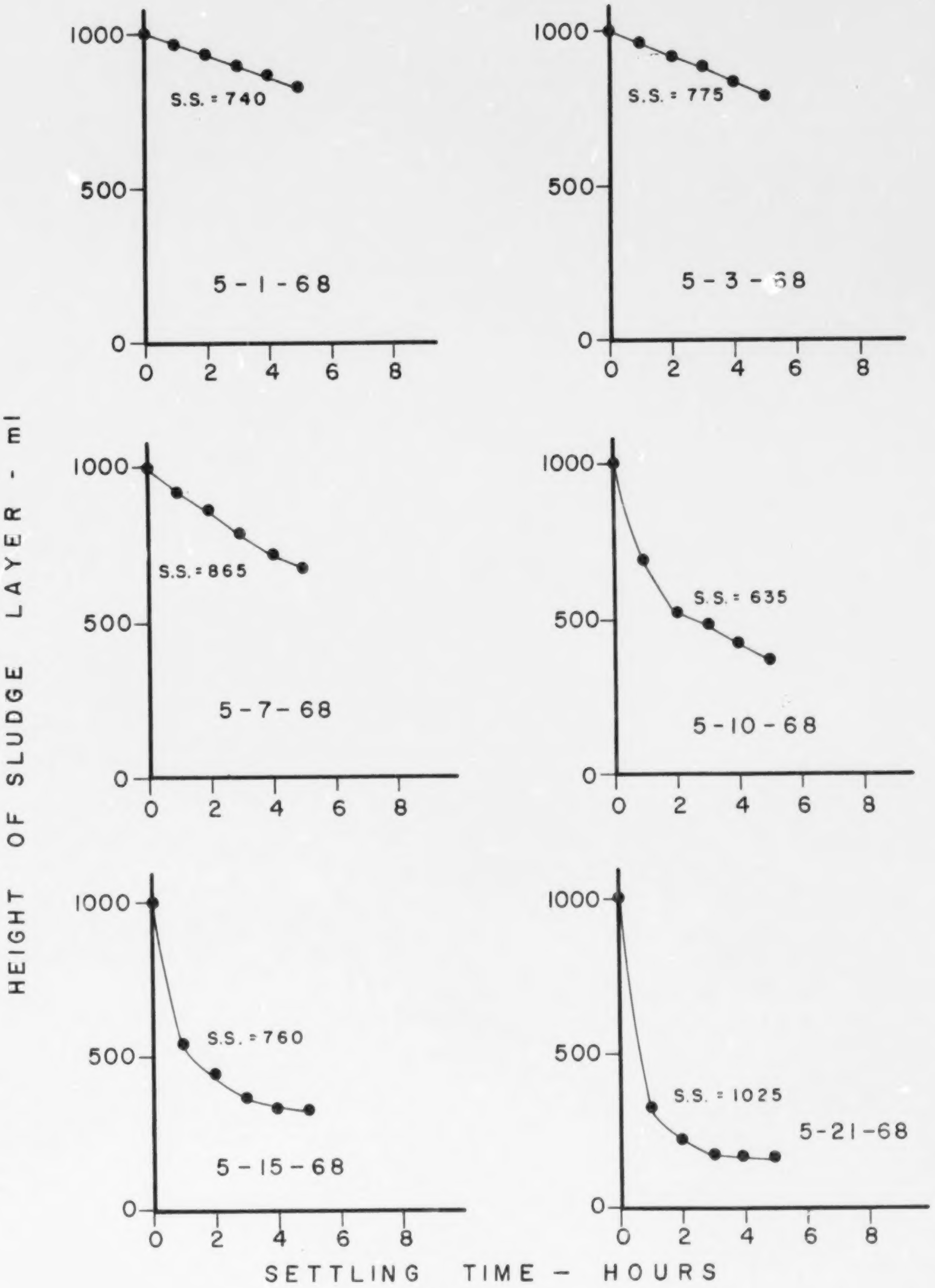

FIG. C-8.— SLUDGE SETTLING CURVES

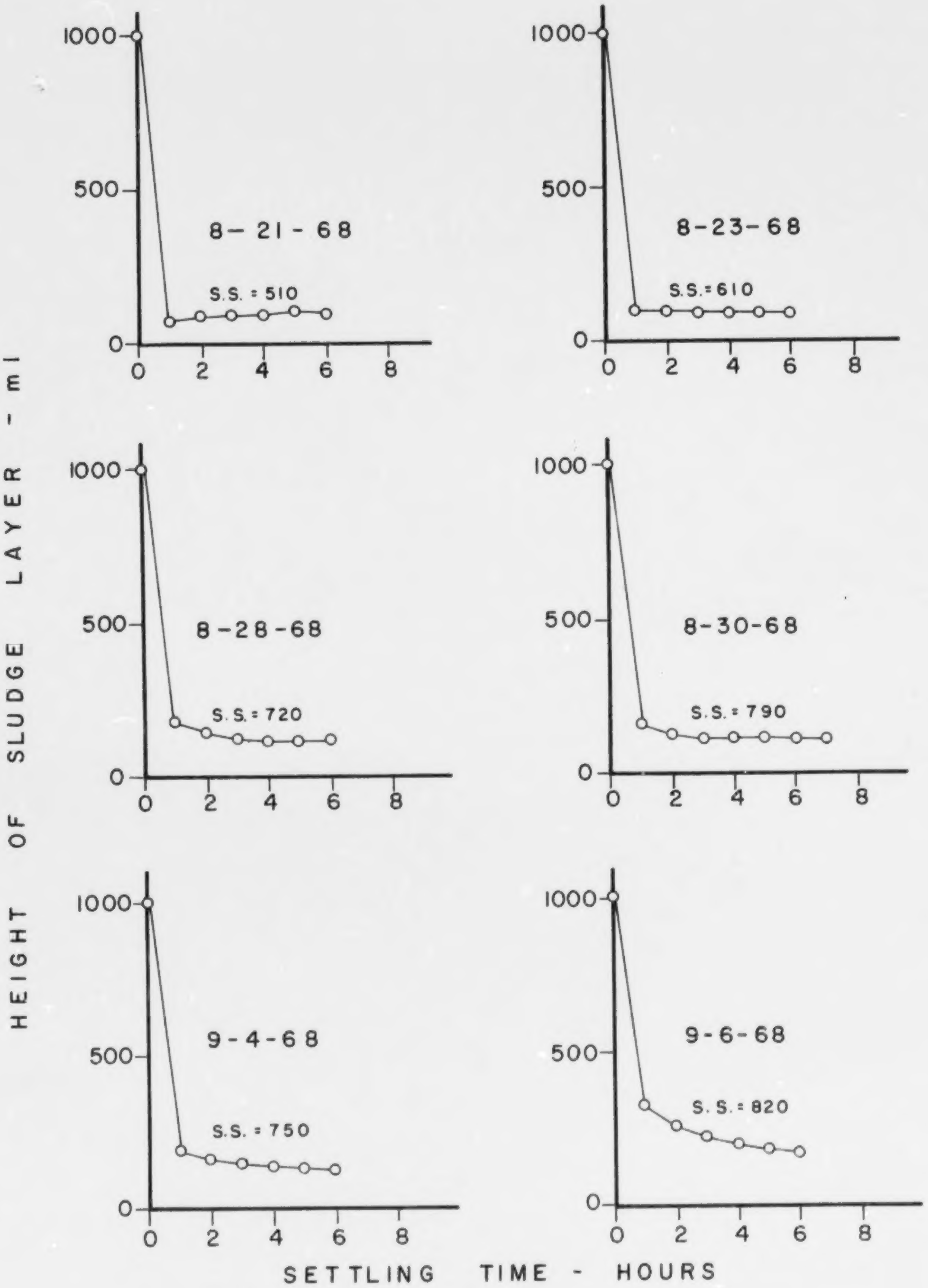

FIG. C-9.— SLUDGE SETTLING CURVES

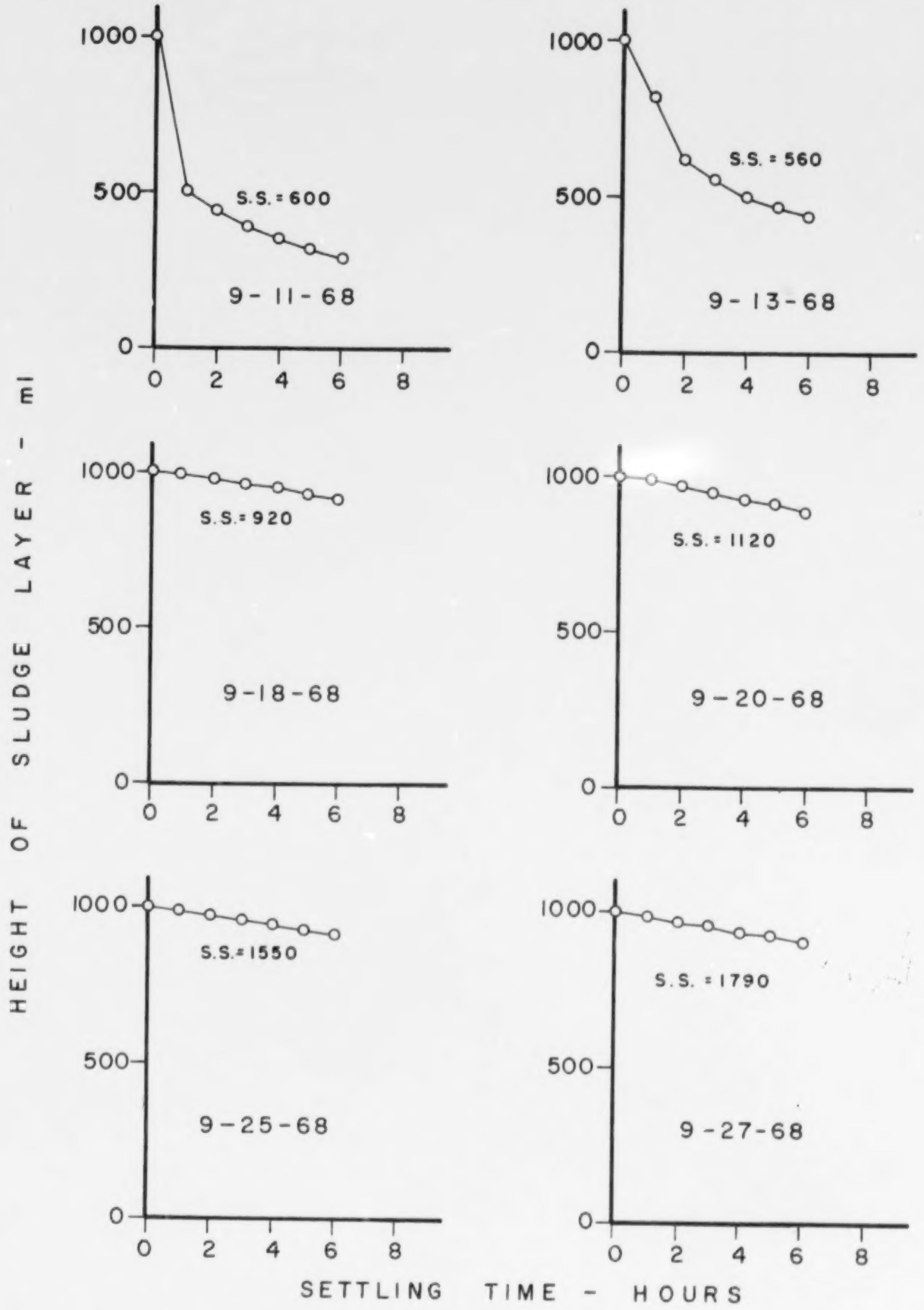

FIG. C-10. — SLUDGE SETTLING CURVES

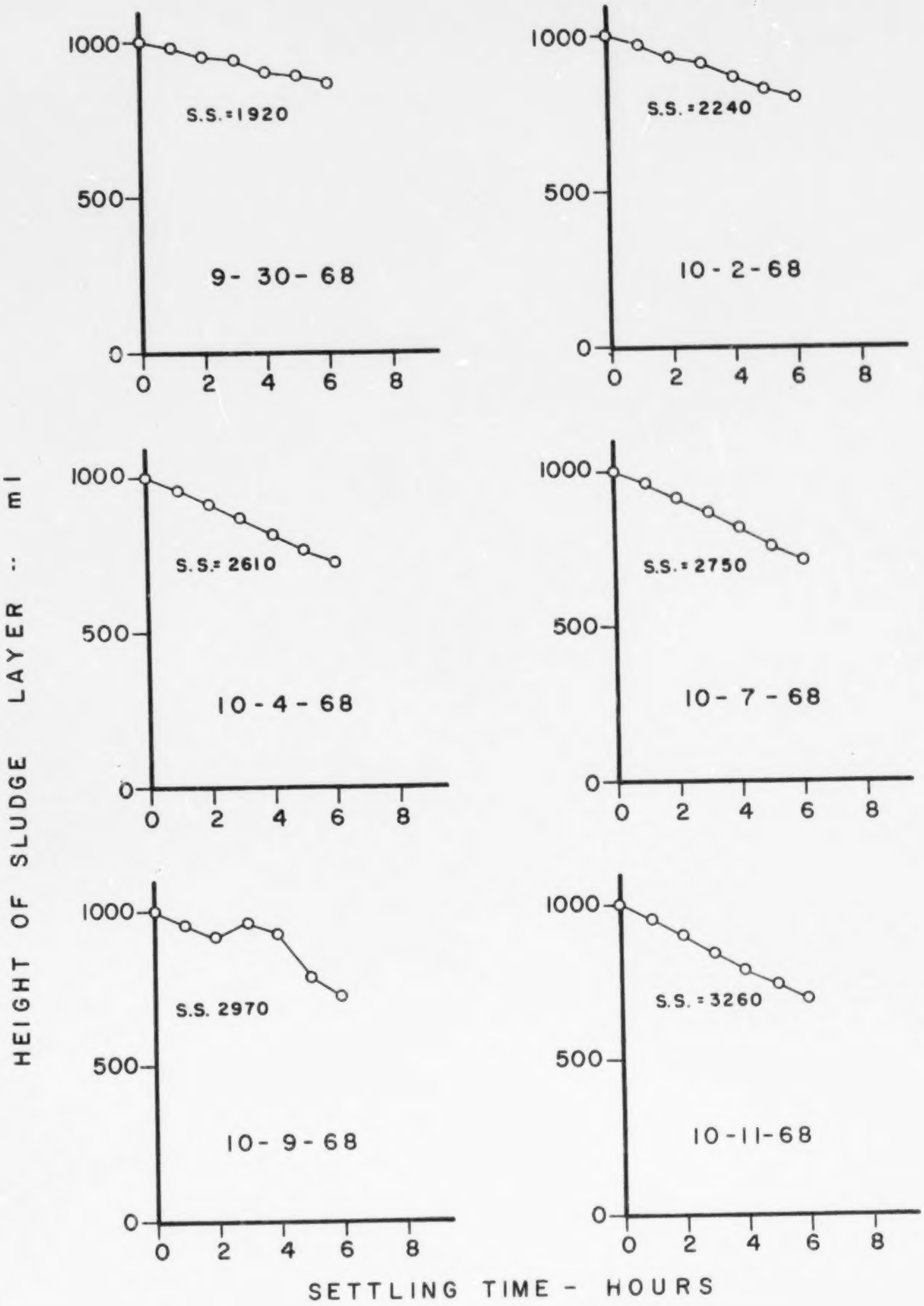

FIG. C-11.—SLUDGE SETTLING CURVES

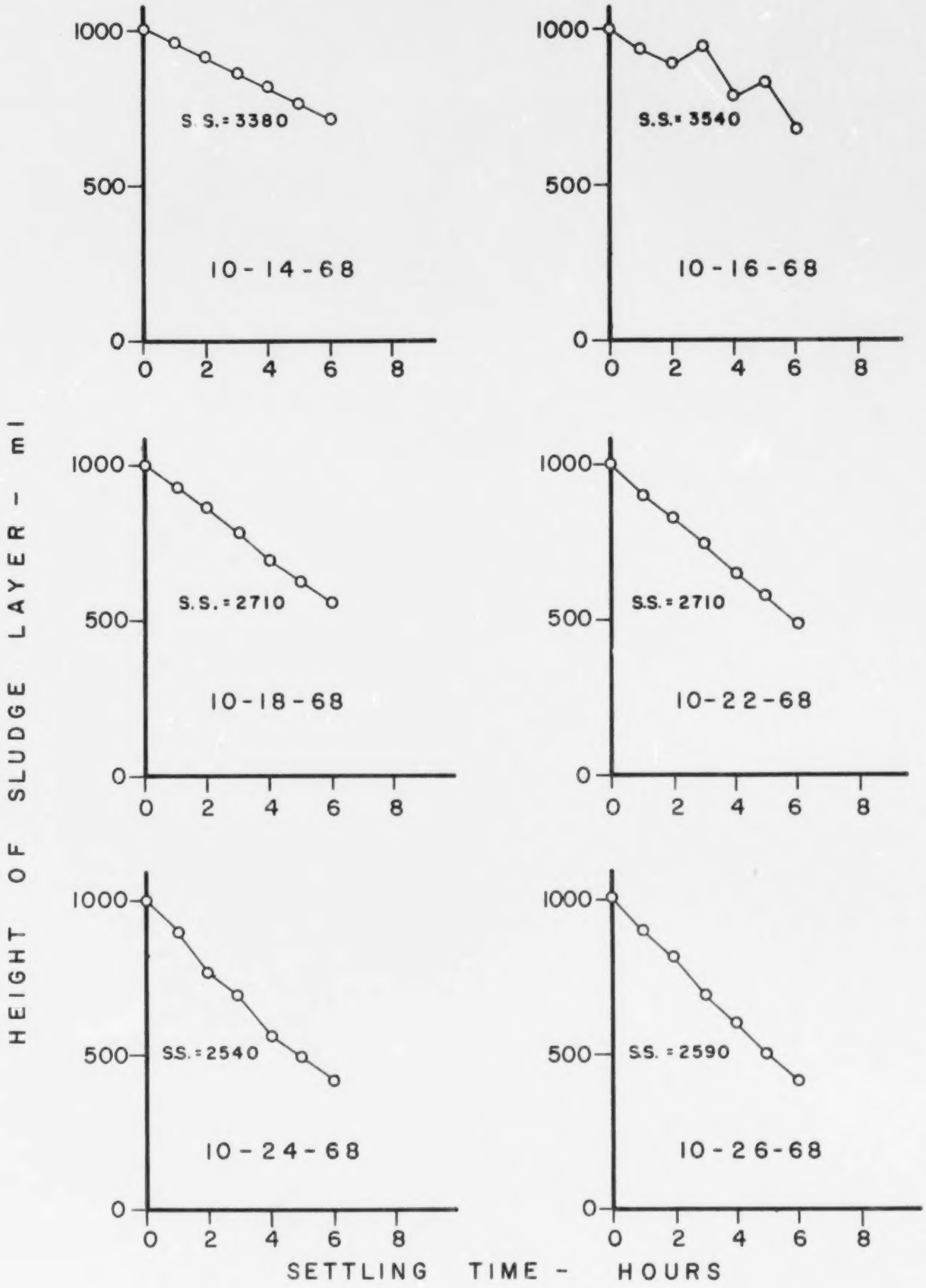

FIG. C-12. — SLUDGE SETTLING CURVES

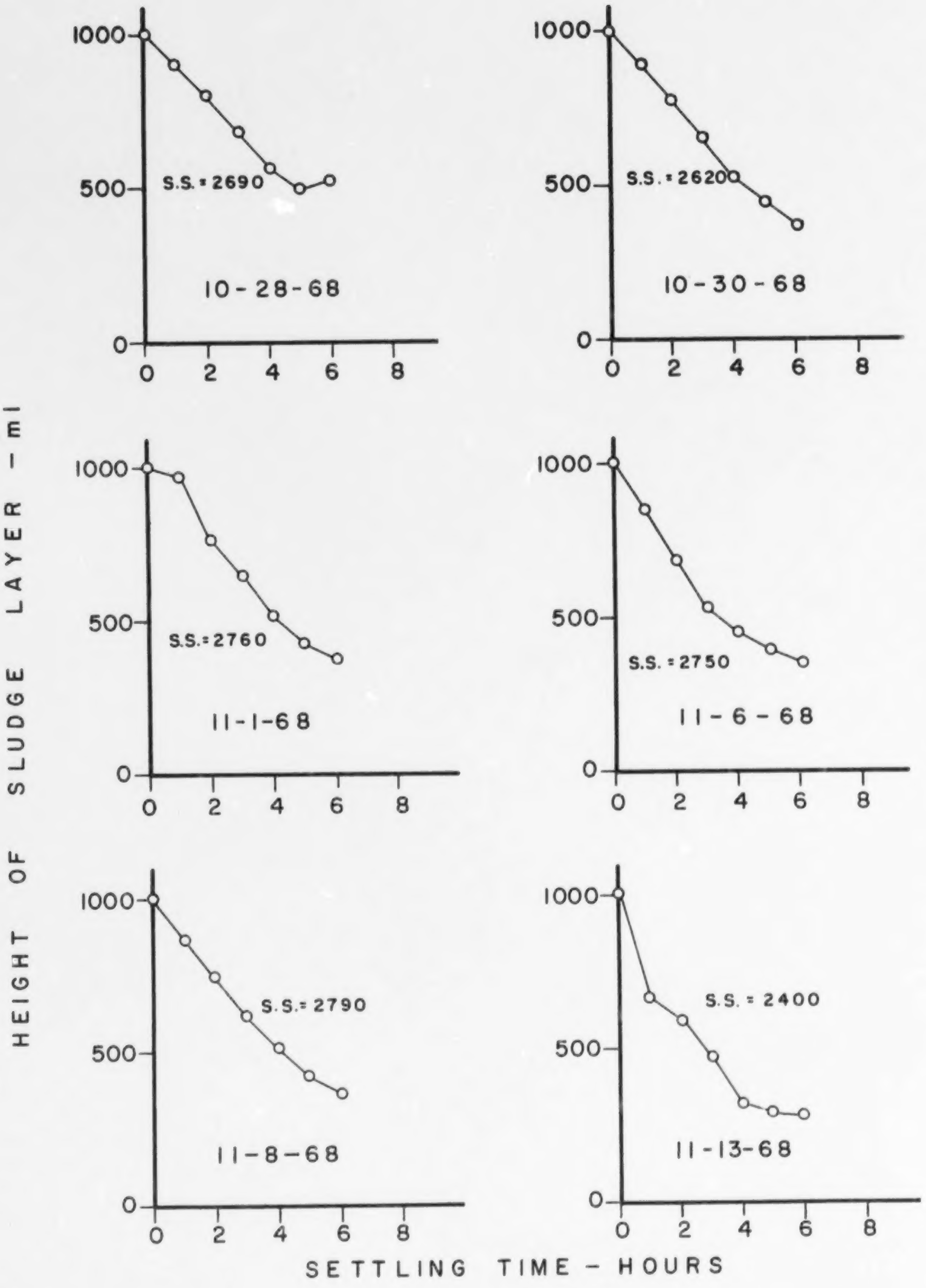

FIG. C-13. — SLUDGE SETTLING CURVES

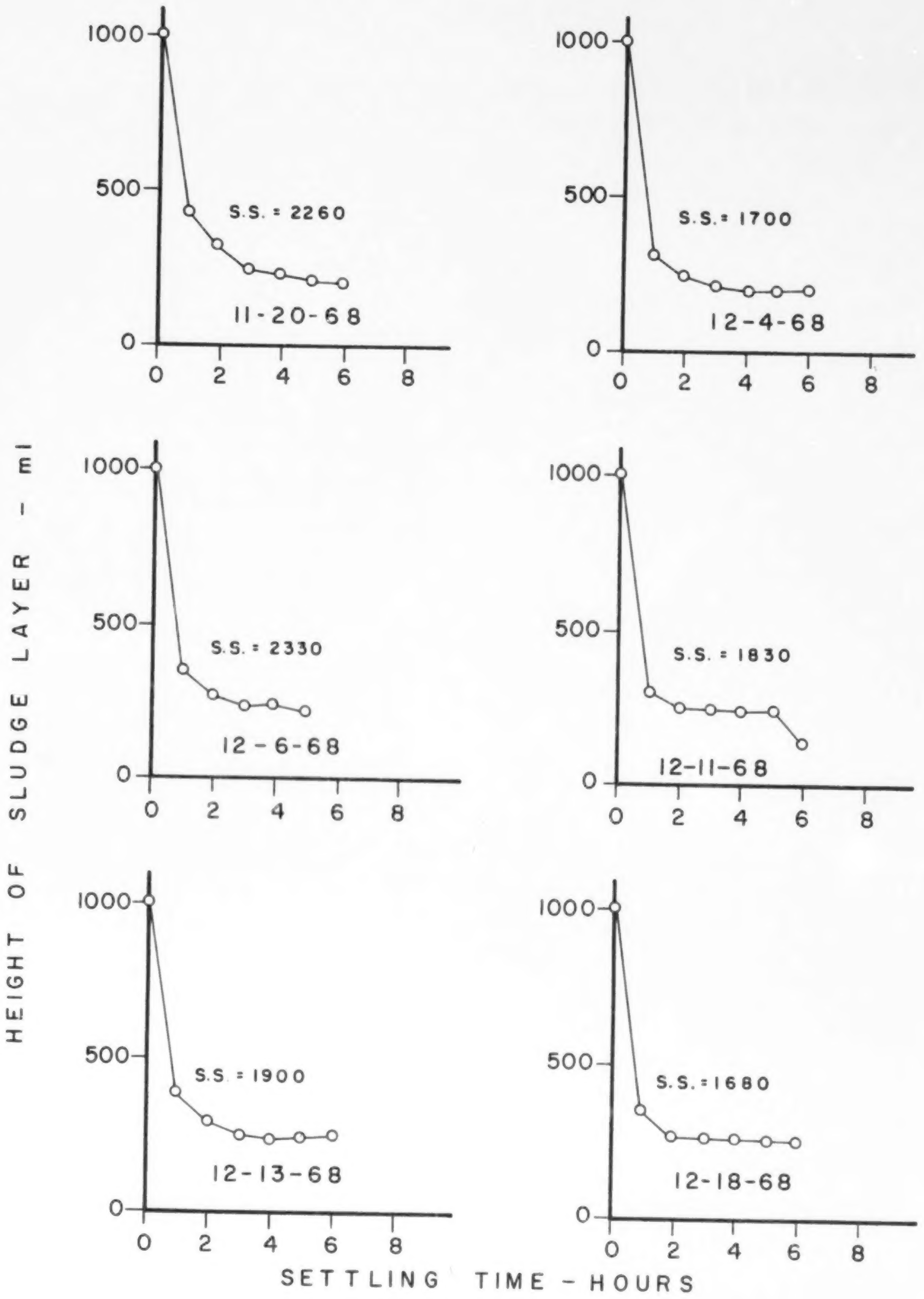

FIG. C-14. — SLUDGE SETTLING CURVES

APPENDIX D

OXYGEN UPTAKE STUDIES

Studies of the oxygen uptake rate of the biological sludge mass were run during both seasons of operation. The testing was run on grab samples taken from the aeration mixed liquor with the use of dissolved oxygen probe and meter. This dissolved oxygen probe and meter made by YSI did not have proper temperature compensation so correction curves were plotted for the meter itself. The standardization point of the meter was recorded at the time of making the uptake rate studies so the correction curves could be used to correct the individual readings during each test. Figure D-1 shows the standardization curve as recommended by the meter manufacturer for standardizing the meter in air according to the water temperature to be tested. This curve is compensated to the altitude at which the tests were run in Yakima. Figure D-2 shows the correction curves as plotted by the study personnel from water of known dissolved oxygen content. The meter readings were corrected to DO in mg/l by finding the standardization reading in air on the lower axis of Figure D-2 going up to the line representing the temperature of the sample at the time of the reading, thence over to the YSI reading over DO in mg/l and dividing the YSI reading by that figure, found on the vertical axis of the correction curves. All of the DO uptake curves were corrected with the use of this chart.

The actual testing was run by taking the sample and placing it in a 2,000 milliliter Erlenmeyer flask, lowering the probe into the flask, sealing the top of the flask with a rubber stopper and placing the flask on a magnetic stirrer for agitation. Each of these samples was aerated vigorously for 30 seconds to one minute prior to placing in the flask in order to assure an ample supply of dissolved oxygen for the organisms in order to establish a curve. It was found that because of the heat emitted by the magnetic stirrer that the samples gained in temperature at approximately a constant rate during the uptake test. The average rate of temperature gain was 6.3° C. per hour and the rate slacked off when the temperature got above approximately 18° C. Normally the temperature was read at the beginning and at the end of the test which made assignment of temperatures to the individual readings relatively easy and which made the correction of the readings relatively easy with the use of Figure D-2. The temperature at which the DO probe and meter were standardized prior to the test was recorded in each instance. Figures D-3 through D-5 contained the DO uptake rate curves run during the 1967-1968 processing season. There were no curves run after October 31, 1967 since the dissolved oxygen probe became unworkable at that time and had to be repaired prior to usability. Figures D-6 through D-8 contain the oxygen uptake rate curves ran during the 1968 season.

As it can be seen, with the gain in temperature the oxygen uptake rate increased so it was attempted to plot the slope tangent to the point at which curve passed through a particular temperature. As it can be seen, this caused more than one temperature and separate DO uptake rates to be recorded. The rate on the figures is the slope of the tangent line divided by the volatile suspended solids.

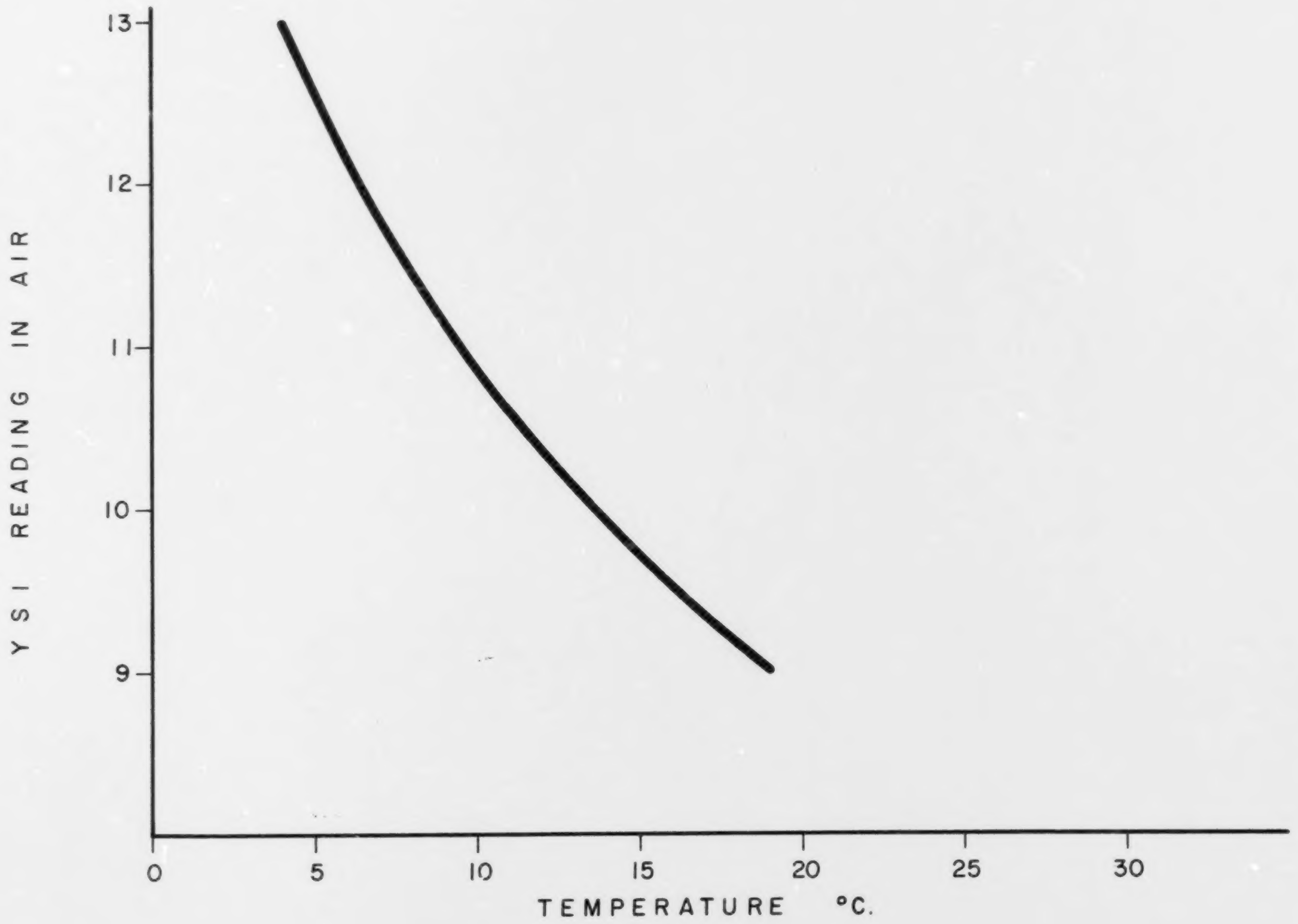

FIG. D-1. — YSI STANDARIZATION CURVE

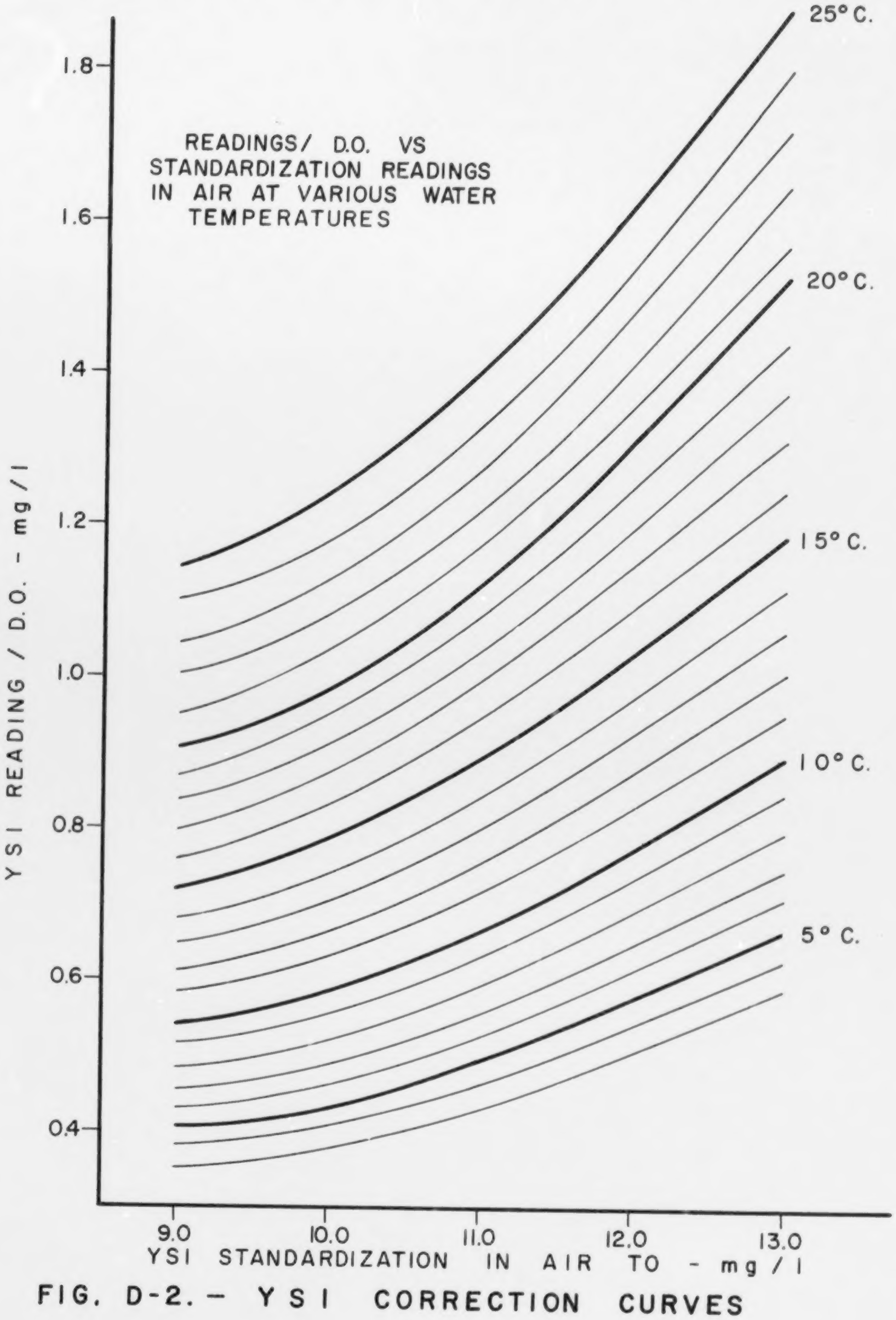

FIG. D-2. – YSI CORRECTION CURVES

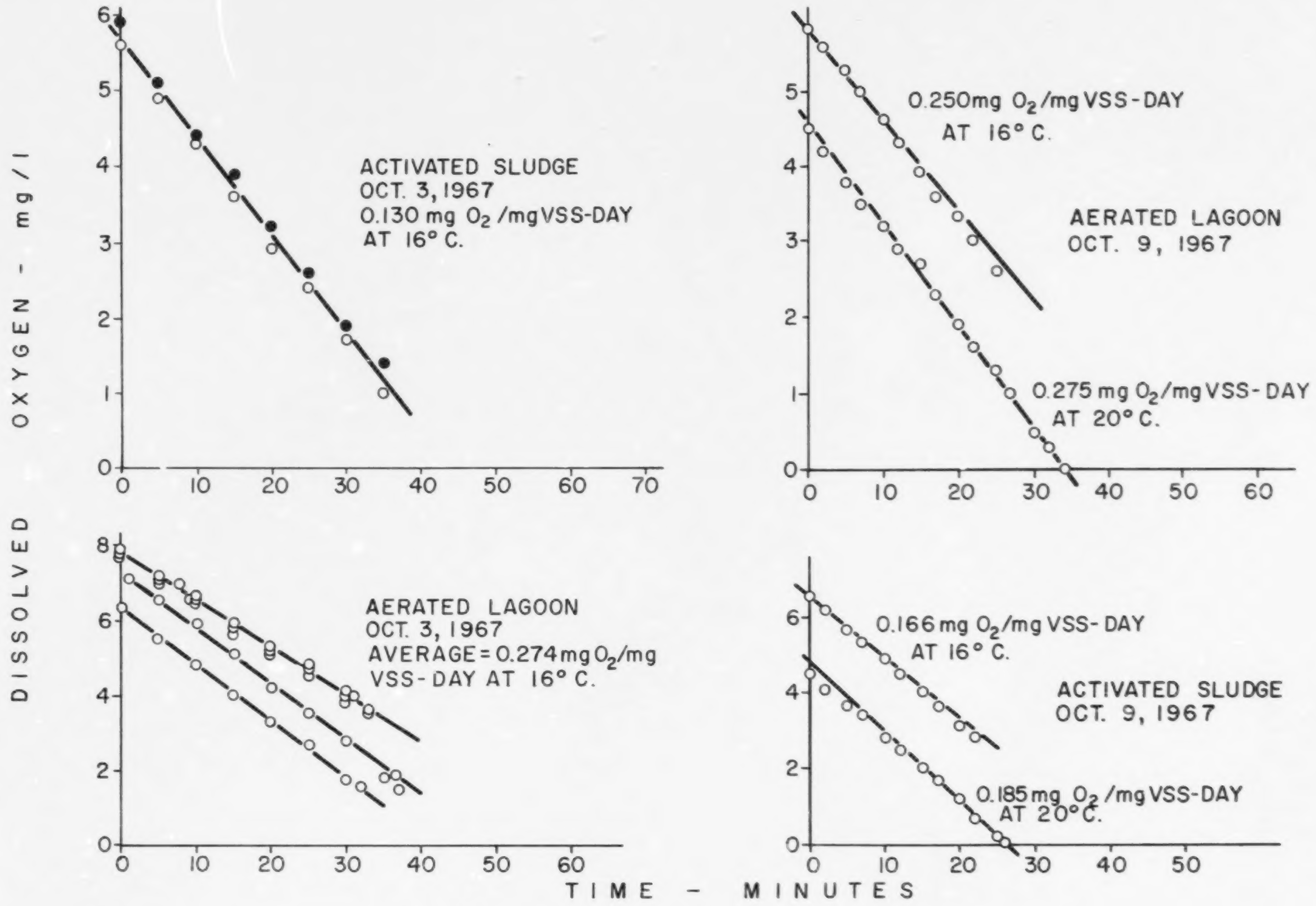

FIG. D-3. — OXYGEN UPTAKE RATE

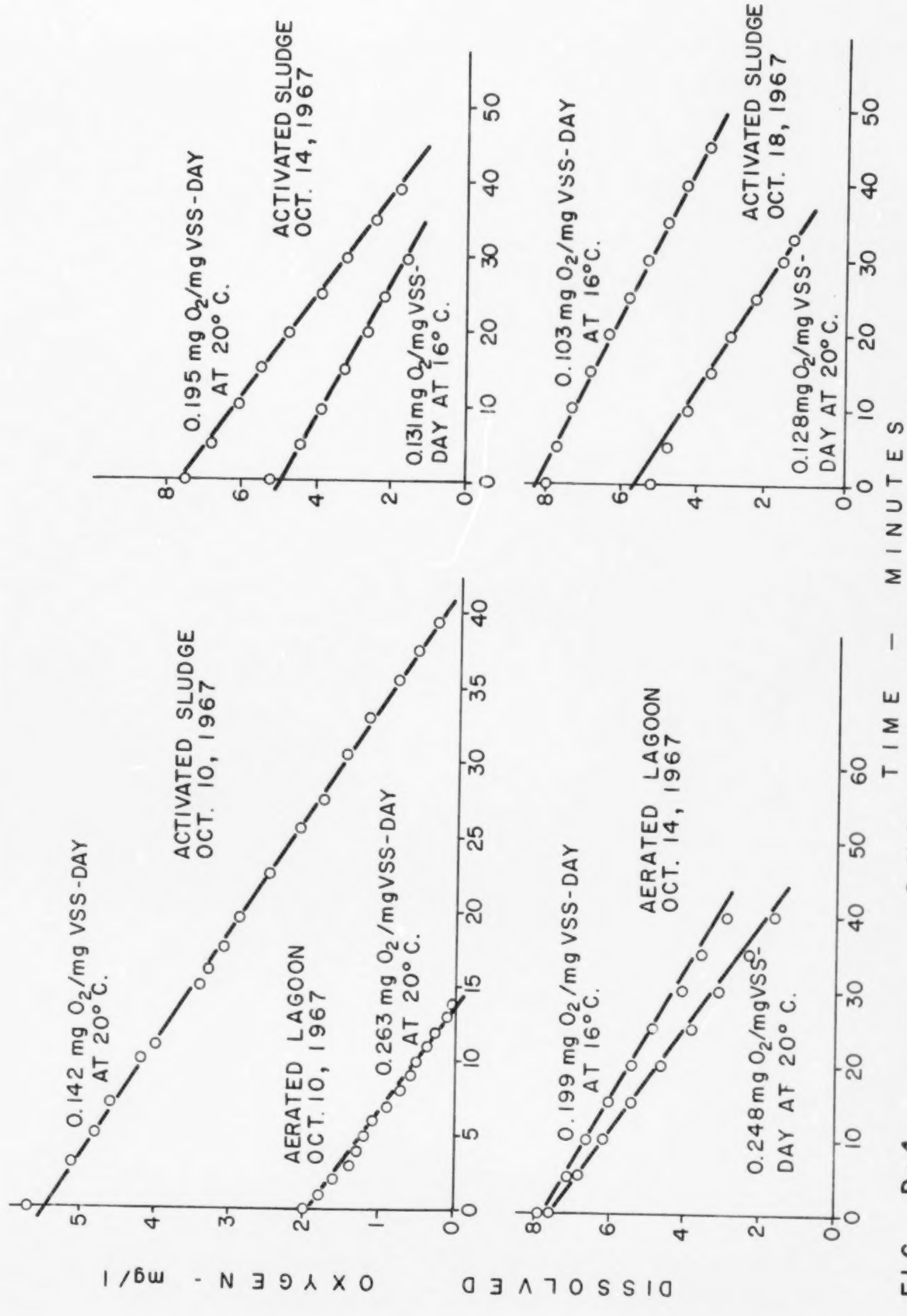

FIG. D-4. — OXYGEN UPTAKE RATE

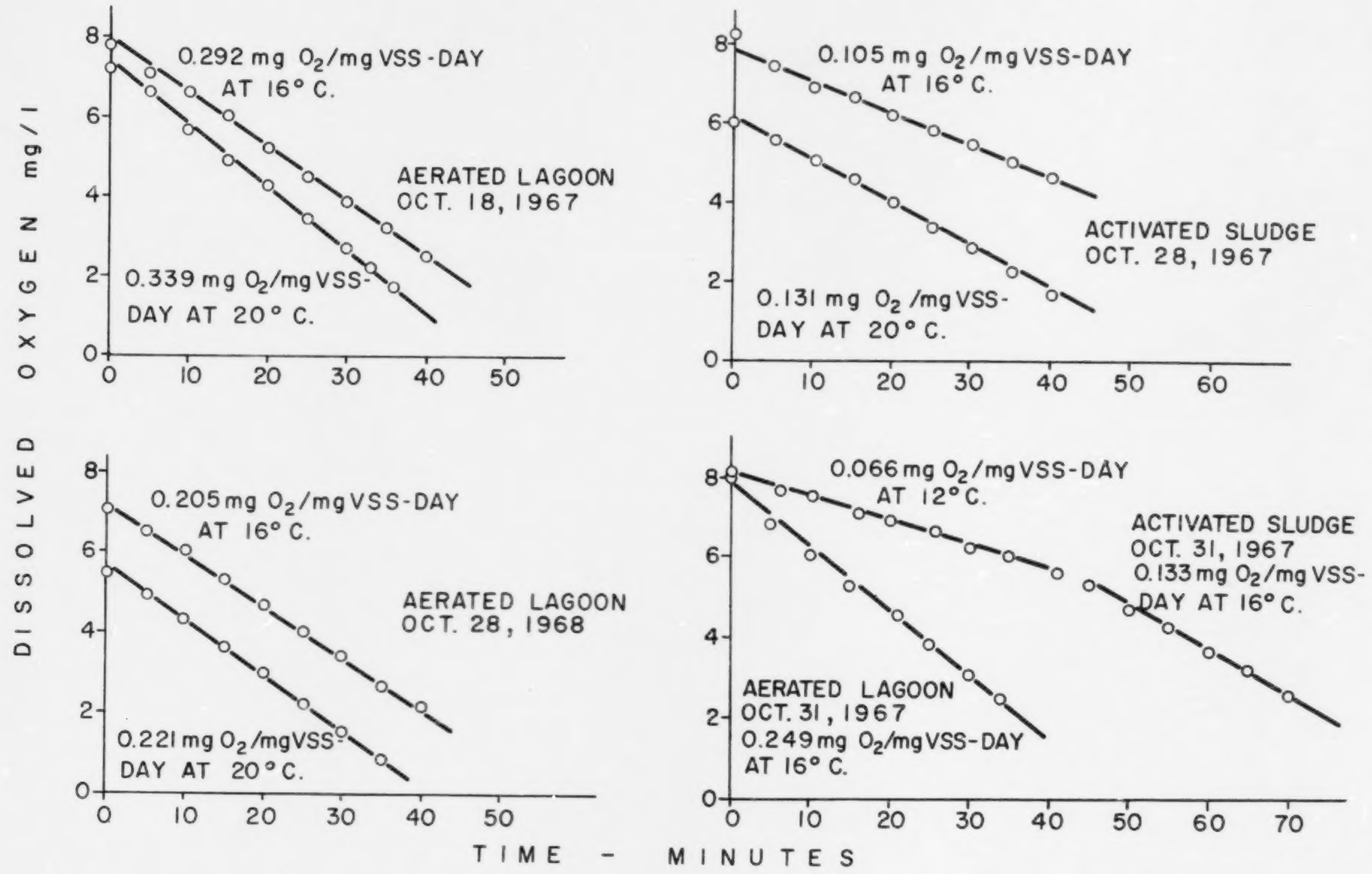

FIG. D-5. — OXYGEN UPTAKE RATE

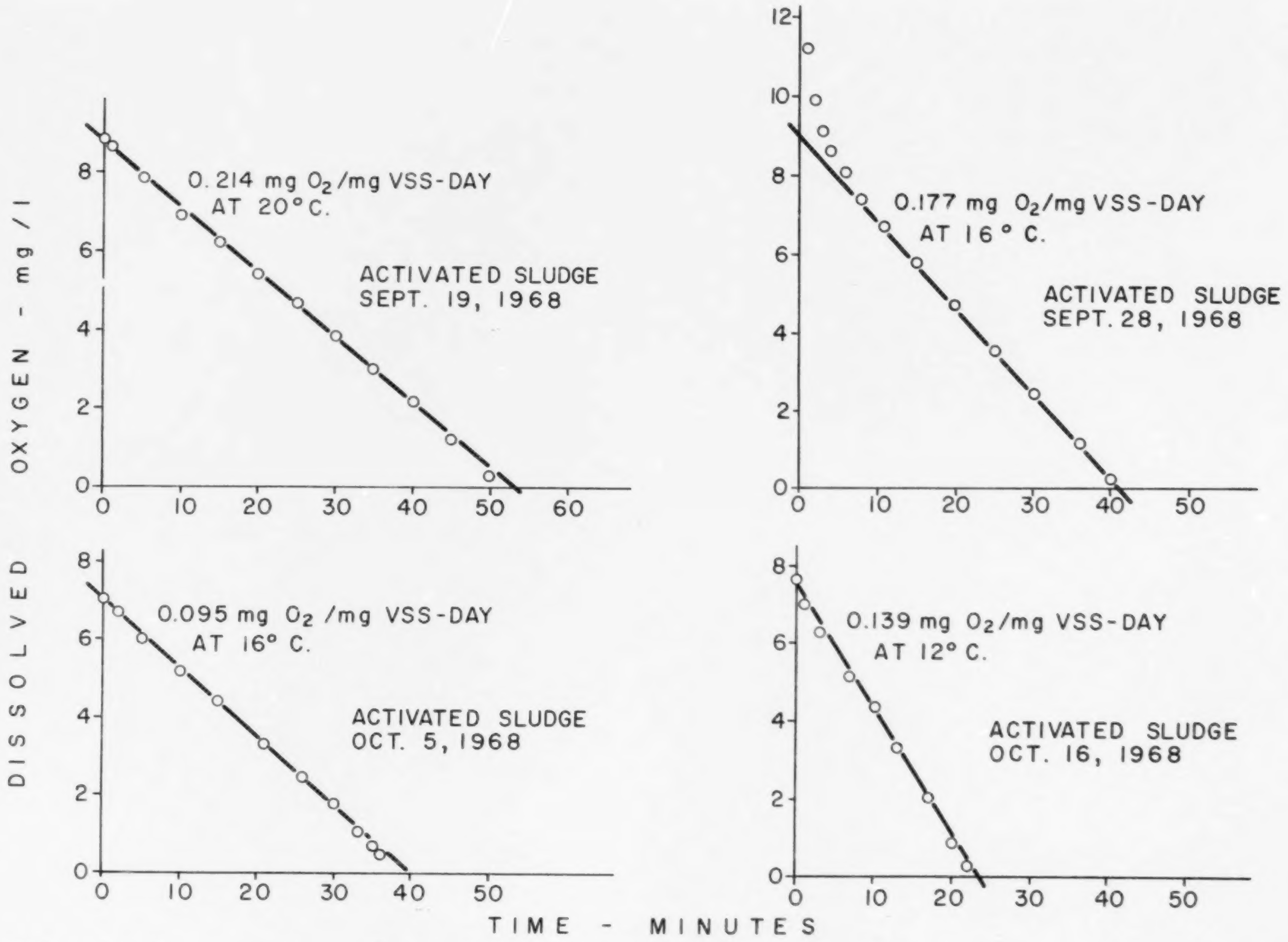

FIG. D-6. — OXYGEN UPTAKE RATE

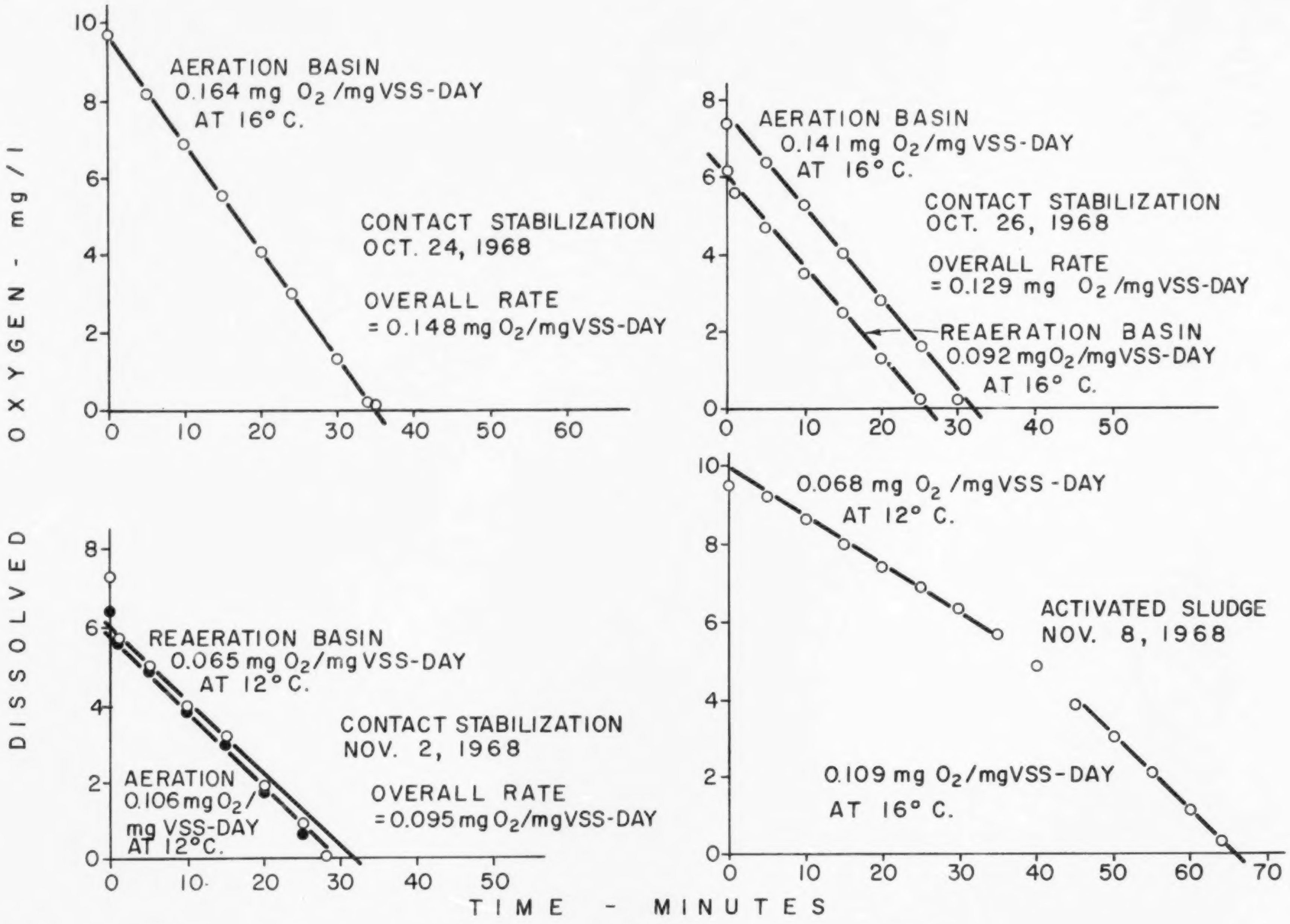

FIG. D-7. — OXYGEN UPTAKE RATE

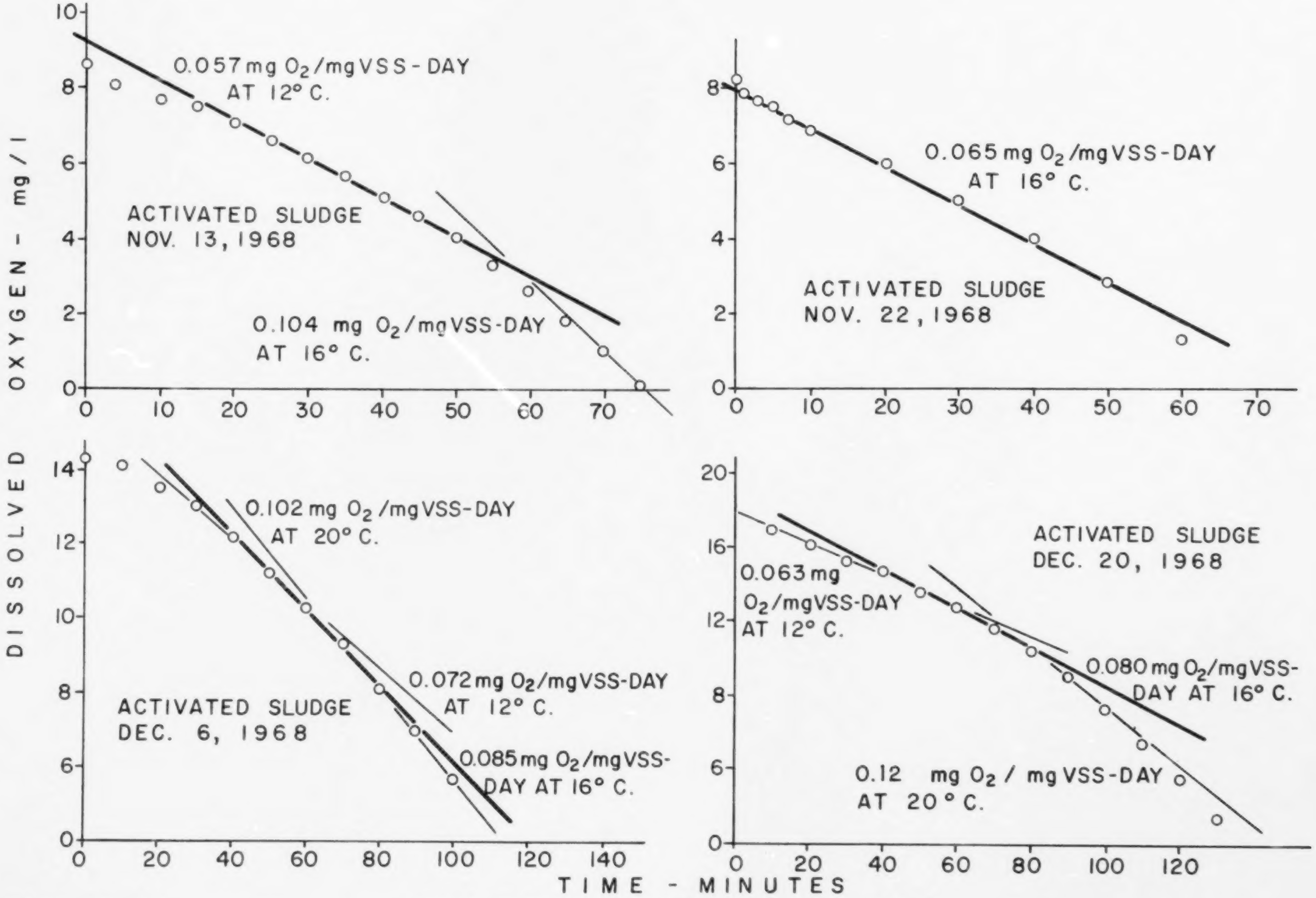

FIG. D-8. —— OXYGEN UPTAKE RATE

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The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States—now and in the future.

MARCH 3, 1849

DAST-8